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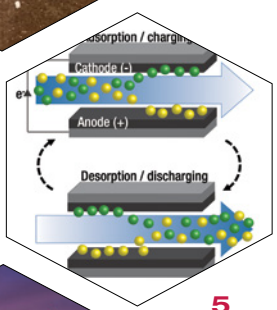

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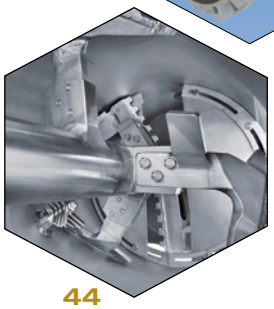

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VERIFIED AUDIT

Editor's Page

The gender gap in engineering

Each year since 2001, the Society of Women Engineers (SWE; www.swe.org) has analyzed the research addressing issues related to women in engineering professions. Last month, SWE released a retrospective analysis [*1*] of what has been learned over the past 20 years. Roberta Rincon, associate director of Research at SWE, says that while women have made great strides in engineering over the last 50 years, gains have plateaued. "In the 70s and 80s, we saw a huge increase in women's representation among engineering degree earners. But in the last 20 years, it's remained relatively stable."

And according to the U.S. Census Bureau "women are still vastly underrepresented in the science, technology, engineering and math (STEM) workforce." It reported that while women have made gains since the 70s, and they currently account for nearly half of the workforce, women account for only 27% of STEM jobs [*2*]. Among the STEM professions, the percentage of women in engineering is the lowest, at about 15%. The numbers are not too different in Canada, where Engineers Canada (www.engineerscanada.ca) reported that about 13% of licensed engineers in 2017 were women.

Workplace retention

Much of the attention given to the gender gap in engineering has focused on attracting women to the profession, particularly through introducing them to science and math early in academic programs. However, once STEM degrees are earned, women are either leaving their jobs, or not entering the workforce. The SWE research shows that about 20% of engineering degrees are earned by women, but the number of female engineers in the workforce is only on the order of 13–14%. The percentages of degrees earned varies by discipline, and the numbers have changed little in the past 20 years. For example, women earned about 37% of bachelor's degrees in chemical engineering in 2002 and about 37.7% in 2020. A look at the U.S. Bureau of Labor Statistics (BLS; www.bls.gov), however, shows that only 13% of chemical engineers employed in 2021 were women.

Research shows that one of the biggest reasons that women leave the engineering profession is the workplace culture. Gender disparity in pay and promotions leads women to feel less valued in the workplace. The sense of not fitting in or belonging in the male-dominated engineering field can be felt as early as a job interview. The SWE report notes that in one study, women were "turned off" by references to a fraternity-like atmosphere during the interview process.

According to McKinsey & Company, companies want to increase the number of women working in technical roles [*3*]. It found that companies with more gender diversity on their executive teams significantly outperformed those with less diverse representation, giving a strong business case for gender diversity [*4*]. In order to retain more women, changes in workplace culture are needed. Positive changes would include improving the pay and promotion disparity between the genders. Other changes to the workplace culture are more complex, and can perhaps begin with awareness and open communication. ■

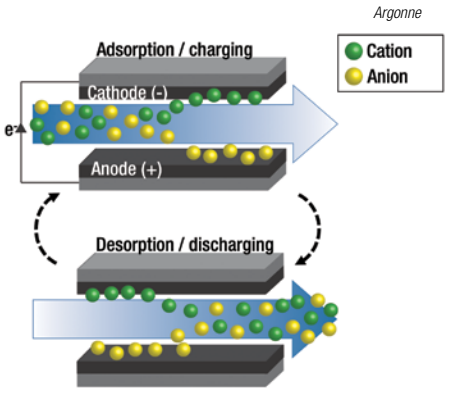
Dorothy Lozowski, Editorial Director

1. Meiksins, P. and Layne, P., Analyzing 20 Years of Social Science Literature, SWE Magazine State of Women in Engineering edition, https://magazine.swe.org/lit-review-22
2. Martinez, A. and Christnacht, C., Women are Nearly Half of U.S. Workforce, but Only 27% of STEM Workers, January 26, 2021, www.census.gov
3. McKinsey & Company, Repairing the broken rung on the career ladder for women in technical roles, March 1, 2022, www.mckinsey.com
4. McKinsey & Company, Diversity wins: How inclusion matters, May 19, 2020, www.mckinsey.com/featured-insights/diversity-and-inclusion

Edited by:
Gerald Ondrey

Applying capacitive deionization for critical-metals recovery

Researchers at Argonne National Laboratory (Lemont, Ill.; www.anl.gov) are investigating an electrochemical separation process known as capacitive deionization (CDI; diagram) to extract and recover ions from liquid streams in wide-ranging applications, including battery recycling and biomanufacturing. CDI holds several advantages over traditional separations techniques, such as distillation and liquid-liquid extraction, because it requires no chemical solvents or phase change. It is currently used in large-scale desalination processes, but it also shows promise in product and resource-recovery applications.



Following dismantling, various components from end-of-life batteries are usually present in a complex, multicomponent liquid mixture, where it can be difficult to efficiently separate critical metals, such as lithium and cobalt, using traditional methods. "CDI gives the ability to target and remove a minority component in a single step. By applying functionalized materials and fine-tuning operational parameters, such as cell voltage, flowrates and the time voltage is applied, we can control ionic separation," explains Lauren Valentino, an environmental engineer at Argonne. CDI cells employ specialized sorbent materials as their electrodes, which can be chemically functionalized to interact with specific ions of interest. "We are looking for materials that have very high surface areas with many sites for adsorption. Our goal is to add specific chemical functionality to the material surface that invokes some selective interaction between the material and the component we are trying to extract," adds Valentino.

For battery recycling, the CDI cells incorporate patented high-capacity sorbents developed by NuMix Materials, Inc. (Chicago, Ill.; www.numixmaterials.com) to adsorb critical metals. Currently, Argonne operates a laboratory-scale cell, which, if operated continuously, has an operating capacity of around 10 L/d. For scaling up the technology, the team will continue to fine-tune the operating parameters, as well as investigate methods to separate the deionized and ion-rich streams in the cell.

Reduced fouling when pneumatically conveying lactose products

To ensure product safety and quality, products containing lactose (at dairy plants, for example) are processed under hygienic conditions. These strict hygiene conditions require frequent cleaning of pneumatic transport systems — typically every eight weeks. This procedure is both labor-intensive and time-consuming, because various components of the conveyor system must be dismantled for cleaning with hot water, and then dried before reassembly to prevent bacterial growth. The entire cleaning process can take several days.

To reduce this effort, Dinnissen Process Technology BV (Sevenum, the Netherlands; www.dinnissen.nl) introduced its new, patented Aeolus pneumatic lactose transport system, which it developed in cooperation with FrieslandCampina (Amersfoort, the Netherlands; www.frieslandcampina.com) — one of the world's largest dairy companies.

In this conveying system, no coatings are used. Instead, the design of the various components, such as curves and switches, has been optimized. Friction, turbulence and wear are minimized by the shape and construction of bends and corners. Because materials scour less around corners, fouling is prevented, says Dinnissen. As a result, production has to be stopped up to 12 times less often for cleaning, which can lead to 8–12% more production days per year, the company says. The savings on labor costs are said to be "enormous." Product quality is also said to be improved, because there is no more accumulation of lactose, and the orifice diameter of the piping remains open during transport.

The Aeolus transport concept is also suitable for conveying other (lactose-free) substances that may be prone to fouling.

NITROGEN UTILIZATION

Late March, the first nitrogen fertilizer produced from a wastewater-treatment plant sidestream was delivered to a farm in Sweden. The fertilizer was produced at a pilot plant that began operation last December at Ragn-Sells Högbytorp's (www.ragensells.se) wastewater-treatment and recycling facility in Upplands-Bo, near Stockholm, Sweden. The pilot plant is part of the E.U.'s LIFE RE-Fertilizer project, which includes partner companies EasyMining AB (Uppsala, Sweden; www.easymining.se), Biofos (Copenhagen, Denmark; biofos.dk), Lantmännen (Stockholm, Sweden; www.lantmannen.com) and Sagn-Sells.

The pilot plant features two mobile units and has a capacity to process 4 m^3/h of water. It is the first industrial-scale demonstration of a patented process, developed by EasyMining, that recovers resources from wastewater with high concentrations of ammonium nitrogen.

According to project manager Anna Lundbom, head of marketing at EasyMining, the currently used biological-based processes just release the nitrogen into the atmosphere after removing it. Instead, the process applied by the nitrogen pilot plant captures it for use in, for example, fertilizers, she said. The new process also would replace conventional denitrification methods that produce emissions of nitrous oxide, a powerful greenhouse gas.

After completing tests last month, the pilot plant was moved to Denmark, where it will operate on reject water from the sewage-sludge dewatering stage of Biofos' Lynetten wastewater-treatment facility.

MINING WASTEWATER

In a related project, several pilot plants were deployed at BBEU (Bio Base Europe Pilot Plant; www.bbeu.org)

(Continues on p. 6)

premises in Desteldonk, Belgium to validate technology developed in the recently completed Afterlife project. In the project, a research team of 14 partners from seven European countries demonstrated the recovery of compounds from wastewater while converting the remaining organic matter into bio-based polyhydroxyalkanoates (PHAs), a biodegradable plastic used in food packaging. The four pilot lines processed 1 m^3/d of wastewaters from: the confectionery industry, cheese manufacturing, and two citrus-fruit processing lines, one of which extracted essential oils and phenolic compounds that can be used in food products.

PDH TECHNOLOGY

KBR, Inc. (Houston; www.kbr.com) and ExxonMobil Catalysts and Licensing LLC (Spring, Tex.; www.exxonmobilchemical.com) are collaborating to advance next-generation propane dehydrogenation (PDH) technology. Under the collaboration, ExxonMobil's new proprietary catalyst technology will be combined with KBR's proprietary K-PRO PDH technology to convert propane into propylene. Enabled by the superior performance of ExxonMobil's new catalyst, the combined technology solution could offer financial savings compared to PDH technologies currently available, says KBR. Potential benefits to existing K-PRO users include increased capacity and reduced operating expenses by upgrading to the new catalyst, the company says.

NEW FCC CATALYST

BASF SE (Ludwigshafen, Germany; www.basf.com) recently launched Fourtitude, a new fluid catalytic cracking (FCC)

(Continues on p. 7)

Catalyst-coated membrane reduces electrolyzer stack cost for H_2 production

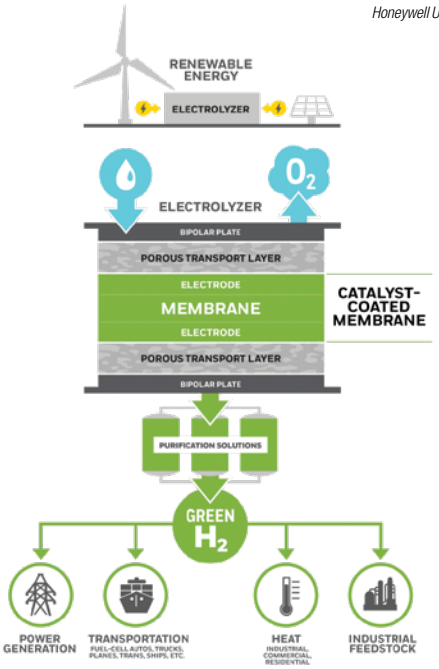
A new catalyst-coated membrane (CCM) technology for hydrogen production, developed by Honeywell UOP (Des Plaines, Ill.; uop.honeywell.com), is undergoing performance validation testing in partnership with manufacturers of proton-exchange membrane (PEM) and anion-exchange membrane (AEM) electrolyzers. Made from both proprietary UOP materials and commercially available materials, the CCM technology is said to achieve higher electrolyzer efficiency and higher current density than currently available CCMs.

UOP employs several methods to apply its proprietary catalysts onto a specially designed membrane to produce the new CCM. With unique composition, structure and morphology, the CCM increases catalyst activity and ionic conductivity, allowing for higher efficiency. The efficiency improvement enables "higher current density that will provide a greater hydrogen production rate," says Amanda Copperthite, Honeywell's Global Head of Strategy, Consultancy and Marketing for STS (Sustainable Technology Solutions).

Honeywell says the CCM can achieve an estimated 25% reduction in electrolyzer stack cost, based on a PEM water electrolysis system using renewable power to produce 2,300 metric tons of H_2/yr with 5,000 operating hours per year. "Because of the efficiency improvements, the PEM electrolyzer system operates with an elevated current density for the same voltage, which reduces the electrolyzer stack size, and therefore reduces the electrolyzer stack cost," explains Copperthite.

Honeywell UOP is now working on scaling up the CCM technology and is also working with partners on long-term performance validation of the CCM.

Honeywell UOP



Commercial debut for a process that makes 'green' pig iron

Last month, Vale S.A. (Rio de Janeiro, Brazil; www.vale.com) began construction on the first commercial plant to use its Tecnored process, which produces pig iron with biomass instead of metallurgical coal (coke). Located in Marabá, in the southeast of Pará, Brazil, the new unit will have an initial capacity to produce 250,000 ton/yr of "green" pig iron, with the possibility of reaching 500,000 ton/yr in the future. The start-up is scheduled for 2025 with an estimated investment of approximately BRL1.6 billion ($341 million).

Developed over 35 years by Tecnored Desenvolvimento Tecnológico S.A. (Pindamonhangaba, SP, Brazil; www.tecnored.com.br), which Vale acquired in 2014, the Tecnored process eliminates the need for coke ovens and sintering, which are process steps used by traditional blast furnaces. As a result, investment and operating costs are reduced by about 15%. By replacing metallurgical coke by biomass, the net CO_2 emissions are reduced by up to 100%, which is said to be an important step in contributing to the decarbonization of the steel industry.

The Tecnored furnace is much smaller in size than a traditional steel blast furnace and is quite flexible in the use of its raw materials, which can range from iron ore fines and steel residues to dam sludge. For fuel, the furnace can be fed by carbonized biomass, such as sugarcane bagasse and eucalyptus. Both are first transformed into briquettes (small compact blocks) and then deposited into the furnace, generating green pig iron.

Initially, fossil fuel will be used to evaluate the performance of the plant, as this will be the first large-scale operation of the technology. "Gradually, we are going to replace coal with carbonized biomass until we reach the goal of 100% biomass", explains Leonardo Caputo, Tecnored's CEO.

Currently, Vale maintains a 75,000-ton/yr demonstration plant that started up in 2011 in Pindamonhangaba, where tests were carried out to develop the technology and its technical and economic feasibility.

PFAS separation-concentration system introduced in North America

A technology initially developed in Australia by OPEC Systems (Emu Plains, NSW, Australia; www.opecsystems.com) for separating and concentrating per- and polyfluoroalkyl substances (PFAS) in a range of water applications has now been introduced in North America.

The technology, known as surface active foam fractionation (SAFF), is an environmentally sustainable separation method that is capable of removing >99.8% of regulated PFAS compounds from water, according to Allonnia (Boston, Mass.; www.allonia.com), the company distributing the technology in North America.

PFAS compounds greater than C6 are amphiphilic, with a hydrophilic head and hydrophobic tail. SAFF takes advantage of this property by bubbling air through the PFAS-containing water such that the PFAS molecules accumulate at the air-water interface. The water to be decontaminated enters a series of reactors with air bubbling through and the PFAS is carried along with the bubbles. The key parameters for effective separation are the dynamics of the tank configuration, the size of the air bubbles and the rate of air introduction, says Nicole Richards, CEO of Allonnia.

Typical PFAS contaminant levels in water samples can range from 200 to 50,000 parts per trillion (ppt) or more, and the SAFF concentrator can reduce PFAS levels down to a few parts per trillion, Richards notes.

SAFF process units are mounted on movable trailers and can be used temporarily at sites for removing PFAS from groundwater, landfill leachate, process water and other water sources, Richards explains. SAFF units are designed to be coupled with a PFAS-destruction technology, such as "PFAS destruction using supercritical water," *Chem. Eng.*, March 2022, p. 8.

SAFF technology works with all PFAS molecules with six or more carbon atoms, but is not as effective for short-chain PFAS compounds, so Allonnia is working on adding a bio-surfactant to the SAFF system to pick up shorter chains.

catalyst designed to maximize butylenes from resid feedstocks. The latest product based on BASF's multiple framework topology (MFT) technology, Fourtitude is optimized to deliver superior selectivity to butylenes while maintaining catalyst activity.

Fourtitude combines the benefits of MFT and metals-passivation technologies to improve the selectivity for butylenes and metals resistance for such applications. The higher butylenes selectivity is achieved by employing a specialty zeolite framework that is more effective at cracking small olefins to butylene. Fourtitude refinery trials have validated its ability to deliver improved performance for refiners through increased butylenes and propylene yields, increased gasoline octane, and improved coke selectivity, BASF says.

PALM OIL ALTERNATIVE

Scientists at the Nanyang Technological University (NTU Sin-

(Continues on p. 8)

gapore; www.ntu.edu.sg) have developed a method to effectively produce and extract plant-based oils from a type of common microalgae. Compared to palm oil, the oil derived from the microalgae contains more polyunsaturated fatty acids, which can help reduce 'bad' cholesterol levels in blood and lower a person's risk of heart disease and stroke. The microalgae-produced oil also contains fewer saturated fatty acids, which have been linked to stroke and related conditions.

NEW MEMBRANE

Researchers at the Massachusetts Institute of Technology (Cambridge, Mass.; www.mit.edu) and Stanford University (Calif.; www.stanford.edu) have developed a new kind of gas-separation membrane that has both a high permeability and a good selectivity — even for gases of similar size. The new family of membrane materials, described in a recent issue of *Science*, is based on so-called hydrocarbon ladder polymers.

Ladder polymers are formed from double strands connected by rung-like bonds, and these linkages provide a high degree of rigidity and stability to the polymer material. These ladder polymers are synthesized via an efficient and selective chemistry — catalytic arene-norbornene annulation (CANAL) — developed at the research laboratory of Yan Xia, associate professor of chemistry at Stanford. The polymers are synthesized in a solution, where they form rigid and kinked ribbon-like strands that can easily be made into a thin sheet with sub-nanometer-scale pores by using industrially available polymer casting processes. The sizes of the pores can be tuned

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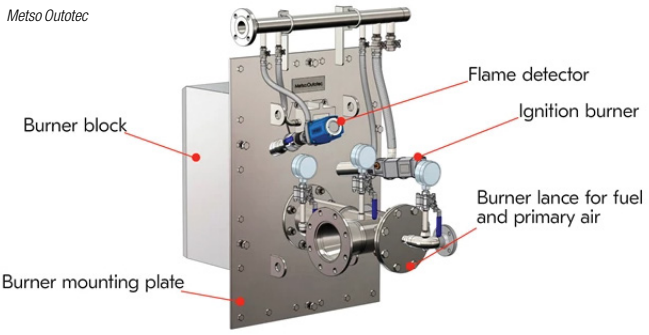
A new burner slashes NOx emissions from iron-ore pelletizing plants

Before being fed to the blast furnace, iron ore is first converted into pellets by, for example, a traveling-grate (TG) pelletizing plant. In this plant, so-called green pellets are conveyed through a furnace that heats the pellets to high temperatures to perform drying, partial calcination and induration. The pelletizing process generates considerable emissions of oxides of nitrogen (NOx), both from the nitrogen in air used for the combustion process, as well as from nitrogen compounds present in the fuel used in the burners. Primary NOx-reduction measures used in different industries are less effective for TG applications, and secondary deNOx measures, such as selective catalytic reduction (SCR), have high capital and operating expenses, explains Andreas Munko, senior product manager, Ferrous & Heat Transfer at Metso Outotec Corp. (Helsinki, Finland; www.mogroup.com).

Because NOx emission limits have been established in many countries, and are also becoming more stringent, Metso Outotec has developed a new burner to solve this challenge. Commercially launched at the end of March, the Ferroflame LowNOx burner for TG pelletizing plants (diagram) substantially reduces NOx emissions by up to 80%, says Munko.



The main operating principle of the new burner is a high-speed dilution of fuel with air using a specially designed burner lance (diagram), along with a slight increase in the primary air-to-fuel ratio, explains Munko. This leads to an improved mixing of fuel and air and a lower fuel content in the combustion mixture. The average and peak temperature in the flame is also reduced in the new burner, which is important because NOx emissions increase at higher temperatures, he says.

The first commercial full-scale application of the burner has been operating since 2019, and the company is now working on a new project that is scheduled for delivery this year. The new burner works seamlessly with natural gas fuel, and tests demonstrate that diesel and coke-oven gas can also be used.

Growing sulfur batteries from crystals

Strain on demand for critical battery metals is forcing manufacturers to seek alternative materials. Sulfur's high thermal stability and abundance are making it a promising emerging battery material. A new class of solid-state lithium-sulfur batteries developed by Theion GmbH (Berlin, Germany; www.theion.de) are produced using similar principles to semiconductor manufacturing in a proprietary, direct crystal imprinting/implanting (DCi) technology that drastically reduces the cost and energy required for producing batteries when compared to typical lithium-ion batteries (LIBs).

For its lithium-sulfur cathode technology, Theion is growing poly-crystalline sulfur wafers with hierarchical porosity down to 15% directly from molten sulfur using carbon-nanotube or graphene seed-crystal carriers. "We are applying a high-voltage electric field to induce growth of a sulfur wafer with tailored porosity by targeting the defect sites present on suitable seed carriers as nucleation points on which one-dimensional nano-sulfur is formed first. Then, as the process propagates along the seed carriers, crystal twinning and branching occurs," explains Theion chief technology officer Marek Slavik. Theion's DCi process enables the targeted addition of conductive paths to maximize active material and optimize energy content. Together, Theion says, these properties result in a battery with triple the range and usage time of traditional LIBs, with a 90% reduction in energy use to produce the batteries. The ability to use sulfur — an inexpensive industrial byproduct — to replace cobalt and nickel further lowers production costs.

"We are currently building a large wafer-growing system for 120-mm sulfur wafers at 15 mAh/cm^2. This is a fundamentally different production process than with typical LIBs, where everything starts as a slurry," explains Slavik. By 2025, Theion expects to operate a gigawatt-scale production line. "The first adopters of the new batteries from the space industry are looking for high-energy options to deliver cargo into orbit," adds Slavik.

Capillary-fed electrolysis unlocks new levels of efficiency for green-hydrogen production

A new category of electrolysis could significantly lower the expenses associated with producing "green" hydrogen. In the new capillary-fed electrolyzer cell — designed by Hysata (Wollongong, Australia; www.hysata.com) based on research from the University of Wollongong (www.uow.edu.au) — water is supplied to electrodes using capillary transport facilitated by a commercially available wicking membrane.

"Rather than having the electrodes surrounded by liquid as in a standard electrolyzer, this wicking membrane takes liquid from a reservoir below the electrodes and delivers targeted electrolyte between the two electrodes. The porous membrane has a very high open area and a much lower electrical resistance than the separators used in other electrolysis methods. This gives us very high current density and low voltages, resulting in a high electrical efficiency with low costs," explains Paul Barrett, CEO of Hysata.

This configuration also means that the electrodes are continuously coated with a thin layer of electrolyte through which the generated O_2 and H_2 gases can efficiently travel without forming gas bubbles, which can hinder access to active sites on the electrodes. Being able to directly produce gases at the electrode interfaces without bubbles or froth in the liquid helps the capillary-fed electrolyzers to avoid resistance and mass-transfer inefficiencies experienced in other electrolyzers, and also decreases the amount of water required. According to Barrett, the new electrolyzers work at 95% overall system efficiency, compared to around 75% for current industry-standard electrolysis units — translating to a H_2 production cost of $1.50/kg or less. "The high-efficiency cells enable balance-of-plant simplification in a number of ways, including eliminating the need for cooling, and we can take the gas off the stack at higher pressure, eliminating the need for compression," he adds.

Hysata has designed the cell architecture to be mass-produced — the cell itself is injection-moldable from widely available polymeric materials, and all other core components, including the wicking membrane, are made of off-the-shelf materials. Furthermore, unlike typical electrolyzers, the electrodes require no precious metals. The team is working on 5-MW cells modules, with gigawatt-scale manufacturing targeted to begin in 2025. These modules will form the building blocks for larger deployments. ■

through the choice of hydrocarbon starting compounds.

Membranes made by the researchers show promise to drastically improve the performance of gas-separation processes. For example, separating CO_2 from methane, these new membranes have five times the selectivity and 100 times the permeability of existing cellulosic membranes for that purpose. Similarly, they are 100 times more permeable and three times as selective for separating hydrogen from methane.

An MIT spinoff company called Osmoses, led by authors of this study, recently won the MIT $100K entrepreneurship competition and has been partly funded by The Engine (www.engine.xyz) to commercialize the technology. ❐

LINEUP

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Plant Watch

ADM announces significant expansions in the U.S. and Germany

April 14, 2022 — Archer-Daniels-Midland Co. (ADM; Chicago, Ill.; www.adm.com) will invest approximately $300 million to significantly expand its Decatur, Ill., alternative-protein production plant. The project is expected to be completed in the first quarter of 2025. ADM is also implementing a multi-million-dollar project, expected to be complete in 2023, to add soybean-processing capabilities at its oilseed facility in Mainz, Germany.

Linde doubles capacity for liquefied gas products at La Porte facility

April 14, 2022 — Linde plc (Guildford, U.K.; www.linde.com) is doubling the merchant liquid production capacity at its La Porte, Tex., site. Starting up in 2024, the increased capacity will help Linde meet growing demand from the petrochemicals, energy, food and aerospace sectors in the U.S. Gulf Coast. It will also supply Linde's existing Gulf Coast pipeline system, which includes nitrogen and oxygen pipelines.

Encina to build advanced recycling plant in Pennsylvania

April 12, 2022 — Encina Development Group (The Woodlands, Tex.; www.encina.com) plans to invest $1.1 billion to build a new advanced recycling facility in Point Township, Pa. to process 450,000 metric tons per year (m.t./yr) of post-consumer materials into feedstock for other manufacturing processes. Construction is expected to begin in late 2022, and the facility is expected to be fully operational in 2024.

Versalis to license ABS technology for new plant in Dongying, China

April 8, 2022 — Eni S.p.A. (Rome, Italy; www.eni.com) announced that its chemical subsidiary Versalis has agreed to license its proprietary continuous-mass technology to Shandong Eco Chemical Co., a Chinese company part of Shandong Haike Holding Ltd. The license will be granted for a 210,000-m.t./yr acrylonitrile butadiene styrene (ABS) unit to be built in Dongying, Shandong province, China.

AGC to expand synthetic pharmaceuticals site in Spain

April 8, 2022 — AGC Inc. (Tokyo; www.agc-chemicals.com) will expand the facilities of its Spanish subsidiary, AGC Pharma Chemicals Europe S.L.U. A new production facility for synthetic pharmaceuticals will be constructed on the company's site, increasing the current production capacity by 30%. The new facility is scheduled to start up in the first half of 2024, with a total investment amount of approximately $100 million.

Ineos Nitriles to build world-scale acetonitrile plant in Cologne

April 7, 2022 — Ineos (London; www.ineos.com) announced that Ineos Nitriles intends to invest in a world-scale acetonitrile production facility in Cologne, Germany. The facility will have a production capacity of 15,000 m.t./yr.

Perstorp to build new carboxylic acids plant in Sweden

April 7, 2022 — Perstorp AB (Malmö, Sweden; www.perstorp.com) will build a new plant on the site of its existing carboxylic acid production operation in Stenungsund, Sweden. This plant will have a production capacity of around 70,000 m.t./yr for carboxylic acids, which will come onstream during 2024. It will be capable of producing acids from C3 to C9 chemistry.

Kraton to expand AMS resins plant in France

April 6, 2022 — Kraton Corp. (Houston; www.kraton.com) announced a significant investment in its alpha methyl styrene (AMS) resins facility in Niort, France, which will result in a 15% production increase at the site by 2023. In addition to the capacity increase, Kraton anticipates the investment will lead to a 70% reduction in solvent consumption.

Veolia launches carbon-neutral bio-methanol project at Metsä Fibre pulp mill

April 6, 2022 — Veolia (Paris; www.veolia.com) has announced what is said to be the world's largest biorefinery project producing CO_2-neutral biomethanol from a pulp mill. The biorefinery, owned and operated by Veolia, will be adjacent to Metsä Fibre's Äänekoski plant in Finland. With a production capacity of 12,000 m.t./yr, the plant is due to come onstream by 2024.

AGC begins production at expanded PVC plant in Indonesia

April 6, 2022 — AGC completed a polyvinyl chloride (PVC) capacity expansion at its Anyer Plant in Banten Province, Indonesia. As a result of the expansion, the group's PVC production capacity has increased by 200,000 m.t./yr up to a total of 1.2 million m.t./yr in Southeast Asia.

Mergers & Acquisitions

LyondellBasell sells Australian polymers business to Viva Energy Group

April 14, 2022 — LyondellBasell (Rotterdam, the Netherlands; www.lyondellbasell.com) agreed to sell LyondellBasell Australia (LBA) to Melbourne-based Viva Energy Group Ltd. LBA is a polymer manufacturer and distributor with a production facility located at the Geelong Refinery. LBA is currently Australia's only polypropylene manufacturer.

Air Products acquires Air Liquide assets in the U.A.E. and Bahrain

April 14, 2022 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) has acquired the following businesses from Air Liquide S.A. (Paris, France; www.airliquide.com): Air Liquide Emirates for Industrial Gases LLC (Alemir); and Orca Industrial Gases LLC, which includes liquid bulk, packaged and specialty gases assets in the U.A.E. The acquisition also includes Air Liquide's majority share in Middle East Carbon Dioxide W.L.L. (MECD), a joint venture (JV) with ALMO Holdings Co., with a liquid-CO_2 production facility in Bahrain.

ArcelorMittal acquires stake in voestalpine's HBI facility in Texas

April 14, 2022 — ArcelorMittal (Luxembourg; www.arcelormittal.com) signed an agreement with voestalpine AG (Linz, Austria; www.voestalpine.com) to acquire an 80% shareholding in voestalpine's hot briquetted iron (HBI) plant in Corpus Christi, Tex. The transaction, under which voestalpine will retain the remaining 20% stake in the plant, values the Corpus Christi operations at $1 billion. The plant, which was opened in October 2016, is one of the largest of its kind in the world, with a capacity of around 2 million m.t./yr of HBI.

Olin and Mitsui establish JV for electrochemical derivatives

April 4, 2022 — Olin Corp. (Clayton, Mo.; www.olin.com) and Mitsui & Co., Ltd. (Tokyo; www.mitsui.com) will establish a joint venture (JV) focused on the companies' electrochemical derivative unit portfolios with initial focus on globally traded caustic soda and ethylene dichloride. The parties expect to commence operation of the JV later this year.

PPG to divest selected business activities in Africa

April 4, 2022 — PPG (Pittsburgh, Pa.; www.ppg.com) has agreed to divest certain business activities in Senegal, Ivory Coast, Cameroon, Gabon and Algeria to Océinde, an industrial group based in Réunion, France. Océinde has a range of business activities throughout Europe, the Indian Ocean region and Africa.

MOL Group acquires plastics recycling company ReMat

April 1, 2022 — MOL Group (Budapest, Hungary; www.molgroup.info) acquired ReMat Zrt., a plastics recycler with production plants located in Tiszaújváros and Rakamaz, Hungary, and a logistics hub in Bratislava, Slovakia. ReMat is a leading recycler in Hungary, with a processing capacity of 25,000 m.t./yr.

Braskem and Sojitz form JV for bio-based MEG and MPG

March 25, 2022 — Braskem S.A. (Sao Paulo, Brazil; www.braskem.com) and Sojitz Corp. (Tokyo; www.sojitz.com) formed a JV focused on bio-based monoethylene glycol (MEG) and bio-based monopropylene glycol (MPG). Subject to the conclusion of technology development in 2022, the business plan includes the construction of three industrial units, with the startup of the first plant expected in 2025.

Mary Page Bailey

SAF Production Expands for a Low-Carbon Future

To lower their climate impact, petroleum refiners are increasingly assessing greenhouse-gas-emission intensities as they consider processing lower-carbon feedstocks. One area of particular activity is sustainable aviation fuels (SAF), where demand growth is accelerating

While the oil-and-gas industry has been on a profitable run since the economic recovery from the pandemic, 2022 has brought a host of complications for the industry, including the ongoing effects of the Russian invasion of Ukraine on fuel markets, and exacerbated supply-chain and labor-force disruptions. These issues are overlaid onto a landscape in which the pressure to transition to climate-sustainable energy and to achieve global net-zero carbon emissions by 2050 continues to grow.

The recently released 6th assessment report from the U.N. Intergovernmental Panel on Climate Change (IPCC; Geneva, Switzerland; www.ipcc.ch) emphasizes the need for aggressive and comprehensive actions to achieve net-zero emissions by mid-century. Stéphane de la Rue du Can, a researcher from Lawrence Berkeley National Laboratory and lead author of the industry chapter, noted "Significant cuts in global greenhouse gas emissions … can be achieved by 2050, but it will require … transformational changes in energy and feedstock sourcing."

The current environmental and geopolitical situation is prompting petroleum refiners across the globe to evaluate their assets and explore how to adapt to a carbon-constrained future, and one in which the negative climate effects of greenhouse-gas (GHG) emissions from fossil fuels will increasingly be priced into refinery products (see sidebox on carbon accounting, p. 16).

One area that has seen a marked uptick in activity and an acceleration in production is sustainable aviation fuels (SAF).

SAF pathways

The International Civil Aviation Organization (ICAO) defines SAF as alternative aviation fuels that achieve net GHG emissions reduction on a life-cycle basis, while respecting conservation of ecosystems and biodiversity, and that contribute to local social and economic development without competing with food and water.

FIGURE 1. Demand for sustainable aviation fuel (SAF) is growing, driven by the commercial aviation industry

Because commercial aircraft are likely to continue to require high-energy-density liquid fuels for propulsion, reducing the GHG emissions associated with commercial air travel and air shipping thus depends heavily on SAF. The aviation industry is expressing its desire for low-carbon SAF through purchasing agreements and collaborations.

In order for the aviation industry as a whole to achieve net-zero carbon emissions by 2050, a massive increase in production of SAF will be required (Figure 1). The International Air Transport Association (IATA) estimates that SAF production would need to reach 449 billion L/yr by 2050 in order to mitigate the majority of global emissions by the aviation industry. Several SAF pathways are currently under development and scaleup, but all face questions of high feedstock and production costs, which are currently substantially higher than conventional jet fuel.

From a processing perspective, SAF production pathways can be grouped into at least four categories, each of which have multiple variations: alcohol-to-jet (ATJ) processes; hydroprocessing of waste fats and oils, and plant-based oils to jet fuel (similar to the hydroprocessed esters and fatty acids (HEFA) process for renewable diesel); gas fermentation with Fischer-Tropsch (F-T) synthesis; and converting sugars to jet fuel.

Perhaps the most straightforward pathway for producing SAF is by hydrotreating triglycerides, such as plant oils, used cooking oils and waste animal tallow (HEFA route). The most technologically mature technologies for achieving this are Topsoe A/S' (Lyngby, Denmark; www.topsoe.com) HydroFlex technology and Honeywell UOP's (Des Plaines, Ill.; uop.honeywell.com) Ecofining technology, co-developed by Eni S.p.A. Others are Axens' (Reuil-Malmaison, France; www.axens.com) Vegan and Sulzer ChemTech's (Winterthur, Switzerland; www.sulzer.com) BioFlux technologies.

Advantages of the HEFA route to SAF include a nominally better liquid yield than ATJ (80 vol.% versus 60 vol.%) and a higher level of technical maturity, explains Dave Collings, senior technical advisory consultant at 1898 & Co. (Kansas City, Mo.; 1898andco.burnsmcd.com). Also, HEFA lends itself better to petroleum refinery conversions, and has lower

FIGURE 2. The aviation industry has been driving demand for SAF through partnerships and purchasing agreements

capital expenses per barrel of SAF product, he adds.

However, feedstock availability issues remain for potential SAF-producing sites. "A shortfall of [non-fossil] triglyceride feedstock afflicts both renewable diesel production and SAF production," comments Collings, "and the prices for those feedstocks are currently very high."

SAF pathways beginning from alcohols or sugars could increase available SAF feedstock and lower costs for SAF, which currently are much higher than conventional jet fuel. Collings says "although the yields for SAF from ethanol are not as high as those from triglycerides, the feedstock costs are much lower — ethanol is only one-third the price of the triglycerides." Further, there is currently more capacity for making renewable ethanol for the ATJ pathway, he adds, and the ATJ route requires less hydrogen.

In places with readily available sugar, such as Brazil, sugar-based ethanol has an advantage over corn-derived ethanol because it's a lower carbon-intensity pathway, explains Collings. In the longer term, processing corn starch into fuels could be competitive with the ATJ processes, he adds.

The corn-starch pathway is the route employed by Virent Inc. (Madison, Wis.; www.virent.com), a wholly owned subsidiary of Marathon Petroleum Corp. (Findlay, Ohio; www.marathonpetroleum.com). Virent is working to commercialize its BioForming process, which makes synthetic aromatic kerosene (SAK; equivalent to jet fuel). The ability to make aromatics-containing kerosene is significant because it allows the plant-based fuel to be used without blending with conventional jet fuel. "Most SAF — such as the fuel typically made from used cooking oil or vegetable oil — has to be blended with petroleum-derived products because it doesn't contain aromatics, which are required to meet today's jet-fuel specifications," says a Marathon spokesperson. "Virent's SAK … provides those aromatics."

Virent upgraded its Madison, Wis., demonstration plant in 2019 to install the latest generation technology that was developed for scale-up and commercial production, Marathon says. Since then, the demonstration plant has run for over 17,000 hours, generating the process engineering data for a commercial plant design, testing the latest generation of catalysts that will be used in the process, and producing material for fuels testing and demonstration projects.

SAF from plant and waste oils

A number of projects for converting used cooking oils and animal fats to SAF are moving ahead using UOP and Topsoe technologies, including a project in China. In March 2022, Honeywell and Oriental Energy Company Ltd. jointly announced that a SAF production facility with an annual output capacity of 1 million tons will be built in Maoming, Guangdong Province, China.

The Oriental Energy SAF project, which will be built in two phases, is expected to be among the world's largest SAF production facilities using used cooking oils and animal fats as feedstocks when completed. Using these feedstocks reduces lifecycle GHG emissions by approximately 80% compared with traditional fuel, Honeywell says.

UOP technology was also selected in February 2022 for a proposed bp plc (London, U.K.; www.bp.com) diesel and SAF project in Kwinana, Western Australia. bp plans to convert hydroprocessing equipment at its former refinery site to produce approximately 10,000 bbl/d of diesel and SAF from renewable feeds, integrating with its existing terminal operations.

Honeywell's Ecofining will be used in the first commercial-scale aviation fuel project in Japan, a facility owned and operated by JGC Holdings and Cosmo Oil. Scheduled to start up in 2025, the project will convert locally collected cooking oil into renewable jet fuel that meets ASTM D7566 standards for jet fuel.

Ecofining also figures in a project looking to expand SAF feedstock options to microalgae. In November 2021, Ecofining was used to generate SAF from oils produced by microalgae. The algae-based SAF was incorporated into a fuel blend that was used to power two commercial flights in Japan.

In September 2021, Honeywell announced a joint multimillion-dollar investment, along with United Airlines, in Alder Fuels LLC (Washington, D.C.; www.alderfuels.com) — a company developing technologies for converting biomass, such as forest and crop waste, into sustainable low-carbon, drop-in replacement crude oil that can be used to produce SAF. Alder technologies, combined with Honeywell's Ecofining process, have the potential to produce a carbon-negative fuel with specifications matching traditional jet fuel, the companies say. The goal of the technologies is to produce fuel that is a 100% drop-in replacement for petroleum jet fuel.

The Alder technology pathway originates with solid biomass converted to a biocrude through fast pyrolysis, then upgraded using the Alder Energy process, the company says. It is then sent to an Ecofining unit or other refinery hydroprocessing unit for conversion to SAF or other transportation fuel (for more information on UOP's Ecofining, see *Chem. Eng.*, May 2021, pp. 12–16).

Meanwhile, in January 2022, Top-

CARBON ACCOUNTING MODELS

Limiting climate-related problems by drastically lowering GHG emissions from fossil-fuel operations and transitioning to sustainable energy in the coming decades requires a nuanced and detailed assessment of how energy assets, including petroleum refineries, are used; an effort that depends on the ability to assess the lifecycle carbon intensity (CI) of different types of oil and gas, as well as other feedstocks, in a standardized way.

Deborah Gordon, former Chevron engineer and current climate policy researcher at the Rocky Mountain Institute (RMI; Basalt, Colo.; www.rmi.org), expresses some of difficulties of the energy transformation this way: "The industry is too close to market pressures and too short-term-oriented to durably alter its course. Uninterrupted operations, quarterly returns, and annual dividends tend to take precedence over emissions reduction, clean-energy transformation and corporate climate alignment," she says. At the same time, "policymakers and civil society sometimes fail to understand the complexities and inherent dynamics of oil-and-gas supply chains and their wide-ranging climate impacts. They do not have to worry about the economic viability of the industry or about pleasing stock-market investors."

Carbon intensity (CI) is becoming more widely used as a metric for assessing the lifecycle emissions of a given fuel. CI is important whether the facility is producing conventional crude oil or is making biofuels. Since it will not be possible to immediately suspend production of fuels from crude oil, reducing overall GHG emissions will require a deep and broad understanding of the ways CI can vary for different types of crude oils.

This is a point made in a recently published book, titled "No Standard Oil: Managing Abundant Petroleum in a Warming World," by RMI's Gordon. "In fact, one [crude oil] barrel can have ten times the climate impact of a different barrel," Gordon says. Currently, this environmental information is not available to inform consumers', policymakers, investors', and citizens' decision-making. "And as a result, oil-and-gas markets are not able to price in climate externalities," Gordon points out.

"If detailed information about the highly varying climate intensities of oils and gases were part of market calculations, producers, refiners, and shippers would compete on a level playing field, and actors with high-emitting resources could be made to pay their fair share to mitigate climate change," she says.

Most international oil companies have come out in support of the government placing a price on carbon, Gordon says, but carbon pricing is an extremely difficult political sell. "Interestingly," Gordon continues, many companies already use "shadow pricing" to place an internal cost on GHG emissions that informs their investment and operating decisions. "This is motivating corporate changes," she says. "Many larger oil-and-gas companies are starting to unload their high-climate-intensity production and refining assets." However, shifting climate-intensive assets onto smaller, lesser-known companies' books may exacerbate global warming, she warns.

A key aspect of the book is the OCI+ (oil climate index plus gas), a new model developed by Gordon and a team of other researchers that is designed as a publicly available web tool that assesses and compares the lifecycle GHG emissions from any barrel of oil (or gas) from extraction through end use. The OCI+ employs the Petroleum Refinery Life Cycle Inventory Model (PRELIM) — developed by Joule Bergerson and her colleagues at the University of Calgary — to calculate emissions from refining crude oil and crude-oil blends.

"The OCI+ is a first-of-its-kind tool that can be used by novices and experts to explore oil-and-gas climate impacts and mitigation strategies," Gordon notes.

"The OCI+'s greatest effect in the refining space is that it can both guide the industry's operations and policymakers' actions in the quest to retrofit and ultimately decarbonize refining. The OCI+ can also be used to illuminate how future changes in product slates (such as biojet fuel) will alter overall emissions from end use consumption," explains Gordon.

Among the OCI+ conclusions is that lifecycle GHG emissions are not correlated with API gravity and sulfur content. Instead, emissions vary greatly depending on overall crude composition, equipment used, fuels used for extraction and processing, hydrogen generation, maintenance regimes, leakage rates and system failures. In accounting for all these variables, the OCI+ estimates GHG emissions more accurately than using API gravity, sulfur or other simple emission factors.

RMI's "go-live" day for the OCI+ web tool occurred last month. The release of the newly expanded OCI+ web tool was accompanied by a major report, titled Know Your Oil and Gas, co-authored by the OCI+ researchers at RMI, Stanford University, the University of Calgary, and Koomey Analytics. This updated model version assesses 600 global oil-and-gas resources — representing 65% of current production. Anyone can use the web tool to quantify and compare oil-and-gas GHG emissions. Interested parties can also download the OCI+'s underlying models, Gordon says.

The OCI+ web tool has numerous functions. Maps locate oil-and-gas resources and overlay them with flaring and methane maps. Total lifecycle emissions can be parsed and compared by region, resource type, and other sorts, Gordon explains. "Users can view supply chain emissions breakouts for CO_2 equivalent and methane-only emissions," she says, and "The analysis tab depicts scatter plots for user-defined variables, including resource age, API gravity, sulfur content and industry versus consumer emissions' responsibility." The OCI+ has a "new scenarios" tab that allows users to explore numerous climate solutions and estimate the reduction potential of different technologies and practices. In addition, the OCI+ includes a full methodology, demonstration videos, peer-reviewed journal articles and other resources.

To further make emissions visible using data analytics to develop climate policies and activate climate markets, RMI plans to use the OCI+ and the expanded open-source climate data it provides to chart decarbonization pathways for the oil-and-gas sector, Gordon says. "One avenue we are pursuing that pertains directly to the global refining sector is green hydrogen, as a full-scale renewable replacement for steam-methane reforming," she points out. "We are also researching petrochemicals and their different processes and emissions that could expand as gasoline demand wanes . . . In sum, we are laser-focused on 1.5°C [global average temperature rise] climate alignment in the oil-and-gas industry during this decisive decade," Gordon says. ❑

soe and Indaba Renewable Fuels announced plans to build two greenfield refineries in California and Missouri to produce SAF with Topsoe's HydroFlex technology. The facilities are expected to begin SAF production in 2024. The capacity of the plants is 6,500 bbl/d at each location. Topsoe will also provide its H2bridge hydrogen technology for both facilities that further replaces fossil fuels with renewable liquids, like LPG or naphtha, to lower the carbon intensity of the products.

HydroFlex was also used in test production runs for SAF and renewable diesel at the Marathon Petroleum facilities in Dickenson, N.D. and Martinez, Calif.

Sulzer's BioFlux technology will be used to make SAF (along with renewable diesel) at the Sabah Maju Jaya Renewable Energy Industrial Complex in Kota Kinabalu, Malaysia. The planned plant, which was announced in February 2022, will use a BioFlux technology package to convert locally sourced plant-based oils into SAF. BioFlux was developed by Duke Technologies Inc. (Fayetteville, Ark.; www.dukebiofuels.com) in the U.S. and licensed by Sulzer Chemtech. The technology is said to be the only licensed technology with a liquid-phase full reactor design that maximizes hydrogen availability and

FIGURE 3. SAF and renewable diesel production has been tested at refineries such as this Marathon Petroleum facility

eliminates the vapor recycle loop. This significantly reduces the capital and operational costs while improving yield and catalyst life, according to Sulzer Chemtech. The new 10,000-m^2 processing complex is slated to deliver an annual production capacity of 250,000 tons.

Axens Vegan technology was selected by TotalEnergies SE (Paris, France; www.totalenergies.com) for its first biorefinery, located in La Mède, France. The plant will produce 500,000 ton/yr of high-quality paraffinic biodiesel, treating primarily used oils, as well as other renewable feedstocks. The Axens technology was originally developed by IFP Energies nouvelles in the mid-2000s.

Axens Vegan technology fundamentally consists in hydroprocessing any kind/mixture of renewable lipids into ultra-clean iso-paraffins. The resulting high quality mixture of bio-paraffins exhibits a high cetane number, tunable cold-flow properties, contains virtually no sulfur neither aromatic compounds and is easily blended into regular diesel or jet fuel, the company says.

Axens also signed a license agreement for the Vegan technology with biofuels company Aemetis Inc. (Cupertino, Calif.; www.aemetis.com) last year.

SAF from ATJ process

The past year has also seen significant activity around the ATJ process, whereby biomass-derived ethanol is dehydrated to ethylene, which is then oligomerized into C12–C15 olefins. The olefins are then saturated to make fuel of the correct composition to meet jet fuel standards.

In March 2022, biofuel maker Gevo Inc. (Englewood, Colo.; www.gevo.com) announced an agreement with Delta Air Lines to supply 75 million gal/yr of SAF for seven years to the air carrier. Also in March, Gevo announced that the Oneworld Alliance, a network of seven airlines, will utilize Gevo's SAF for their operations in California, including San Diego, San Francisco, San Jose and Los Angeles International Airports.

Meanwhile, LanzaJet, a fuel-making company spun off from LanzaTech Inc. (Chicago, Ill.; www.lanzat-

INVESTOR INFLUENCE

Both individual and institutional investors are becoming increasingly concerned with environmental, social and governance (ESG) criteria when making financing decisions, and are demanding more information about climate risks to which companies may be exposed.

"Investors are putting growing pressure on oil-and-gas companies to report their 'Scope 3' (end-use) emissions that come from burning the wide array of petroleum products refiners sell to consumers," RMI's Gordon says. "Publicly accounting for end-use emissions is the first step to factoring in their negative externalities — and rethinking their business model," she argues. "Moreover, as demand wanes for certain petroleum products (such as gasoline as electric vehicles replace internal combustion engines) and various renewable feedstocks are converted into bio-based fuels, refiners will be compelled to redesign their processes. Factoring decarbonization into these renovations will offer refiners a competitive edge in the global marketplace," Gordon says.

In March 2022, the U.S. Securities and Exchange Commission (SEC; Washington, D.C.; www.sec.gov) proposed rule changes (which are now open for comment) that would require registrants to include certain climate-related disclosures in their registration statements and periodic reports, including information about climate-related risks that are reasonably likely to have a material impact on their business, results of operations, or financial condition, and certain climate-related financial statement metrics in a note to their audited financial statements. The required information about climate-related risks also would include disclosure of a registrant's GHG emissions, which have become a commonly used metric to assess a registrant's exposure to such risks.

The proposed SEC rules would include a phase-in period for all registrants, with the compliance date dependent on the registrant's filer status, and an additional phase-in period for Scope-3 emissions disclosure, according to SEC. ❑

ech.com), announced a partnership with Marquis Sustainable Aviation Fuel in February 2022 to construct a 120-million gal/yr integrated sustainable fuels plant at Hennepin, Ill. Using the LanzaJet ATJ process, the plant will employ on-site carbon capture and sequestration and renewable energy to produce SAF, resulting in a lifecycle greenhouse gas reduction of more than 70% compared to conventional jet fuel.

And in January, LanzaJet announced a $50-million investment from the Microsoft Climate Innovation Fund to support construction of its Freedom Pines Fuels plant in Soperton, Ga. The ATJ SAF production plant is expected to achieve mechanical completion in 2022 and begin producing 10 million gal/yr of SAF and renewable diesel from sustainable ethanol, including from waste-based feedstocks, in 2023.

Another ATJ technology is that of Vertimass LLC (Irvine, Calif.; www.vertimass.com), which originated at Oak Ridge National Laboratory as a way to lower the cost of converting alcohols to hydrocarbons by utilizing a single reactor. In February 2022, Vertimass announced a collaboration with U.S. biofuels maker World Energy for the development of Vertimass technologies for SAF and other renewable fuels.

F-T synthesis

Still other SAF projects are looking to utilize CO_2 as a carbon-negative feedstock for liquid fuels. Several concepts reduce CO_2 to CO, which is then combined with hydrogen to make synthesis gas (syngas). The syngas can then be converted into longer-chain alkanes using F-T synthesis, and refined further into SAF or other products.

A new development related to this SAF pathway occurred in January 2022, when Johnson Matthey (JM; London, U.K.; www.matthey.com) launched HyCOgen, a process designed to enable the production of SAF from CO_2. A new proprietary catalyst, developed by JM engineers, catalyzes the reverse water-gas shift reaction, in which CO_2 and H_2 are combined to generate CO and water.

Paul Ticehurst, JM senior business development manager, says the new catalyst has been integrated into a process that provides a route to SAF that consumes CO_2 in a circular way.

The HyCOgen process is integrated with the FT-CANs process, co-developed by JM and bp plc, in ways that maximize efficiencies to make synthetic crude (F-T liquids), which could then be upgraded by refiners into SAF.

"JM has a deep and detailed understanding of the water-gas shift reaction, so we approached the challenge of reversing the reaction as a syngas-generating technology using that foundational knowledge and applying it to the new process," Ticehurst says.

Because the process is endothermic and requires high temperatures, JM engineered the metallurgy of the process equipment to handle the elevated temperatures reliably over time, Ticehurst notes.

Ninety percent of the carbon in the initial CO_2 leaves the process in FT liquids. "I think of HyCOgen as borrowing molecules that we don't want in the atmosphere and converting them to a form that has an established supply chain," says Ticehurst. "They are converted, used as fuel and returned to the atmosphere, so it's circular, and we get the power." The circular aspects of the technology are maximized when the H_2 used results from water electrolysis powered by renewable energy.

Ticehurst reports "immense interest" in the technology since the January launch, and notes that JM sold its first license for HyCOgen in March. The deal will be announced in the coming months.

F-T synthesis is also a key part of solar fuels. Synhelion (Lugano, Switzerland; www.synhelion.com) has developed a proprietary process that converts solar heat into syngas. This syngas is then fed into a modular synthesis plant and converted into liquid fuels via Fischer-Tropsch.

Synhelion is currently implementing an industrial-scale plant to produce sustainable kerosene from solar energy in Jülich in North Rhine-Westphalia, Germany, and has chosen Ineratec GmbH (Karlsruhe, Germany; www.ineratec.de) as its partner for the fuel production from the solar syngas.

The partners plan to rapidly scale their fuel production with support from industry partners such as Swiss International Air Lines and Lufthansa.

The F-T route also figures in a power-to-fuels project in Germany, directed by the carbon offset not-for-profit organization Atmosfair (fairfuel.atmosfair.de). Atmosfair is building an e-kerosene plant in Emsland, Germany that is capable of producing carbon-neutral SAF.

Conversion projects

A number of large biofuels projects moved ahead over the past year with the involvement of traditional petroleum refiners converting conventional petroleum operations into renewable-fuel production sites.

For example, in September 2021, Shell plc (London, U.K.; www.shell.com) announced a final investment decision to build an 820,000-ton/yr biofuels facility at the Shell Energy and Chemicals Park Rotterdam, the Netherlands (formerly known as the Pernis refinery). Once built, the facility will be among the largest in Europe to produce SAF and renewable diesel from waste. Advanced production methods will be used to make the fuels, Shell says.

As part of its "Powering Progress" strategy, Shell is transforming its refineries (which numbered 14 in October 2020) into five energy and chemicals parks. Shell aims to reduce the production of traditional fuels by 55% by 2030 and provide more low-carbon fuels, such as biofuels for road transport and aviation, and hydrogen. The Rotterdam facility is the second to be announced, following the launch in July of the Energy and Chemicals Park Rheinland, in Germany.

The Rotterdam biofuels facility is expected to start production in 2024. A range of certified sustainable vegetable oils, such as rapeseed, will supplement the waste feedstocks until even more sustainable advanced feedstocks are widely available. The facility will not use virgin palm oil as feedstock. SAF could make up more than half of the capacity, with the rest being renewable diesel, Shell says. Shell can adjust this mix to meet user demand.

In France, the TotalEnergies (Paris, France; www.totalenergies.com) Normandy platform started production of SAF in March 2022. This new site complements the company's existing biojet-fuel production capacity. This move enables TotalEnergies to meet demand from its customers and respond to French legislation, which calls for aircraft to use at least 1% SAF effective January 1, 2022. In April 2022, Airbus powered two flights on its A380 aircraft using SAF that was made by TotalEnergies.

Neste Oyj (Espoo, Finland; www.neste.com) will modify its existing renewables production capacity in Rotterdam, the Netherlands, to enable production of SAF. Currently the refinery produces mainly Neste MY Renewable Diesel. The modifications to the refinery, an investment of approximately €190 million, will enable Neste to optionally produce up to 500,000 ton/yr of SAF as part of the existing capacity.

Neste expects the project to be completed in the second half of 2023. Together with the company's ongoing Singapore refinery expansion, Neste will have the capacity to produce 1.5 million ton/yr of SAF by the end of 2023. Currently, Neste's sustainable annual SAF production capacity is 100,000 tons. Neste MY SAF, in its neat form, reduces greenhouse gas emissions up to 80% compared to fossil jet fuel takling into account the full lifecycle, Neste says.

In February 2022, bp, which created a specialized international aviation fuel products and services division known as Air bp, began producing SAF from used cooking oil. The bp plant in Lingen is the first industrial production facility in Germany to use co-processing to produce SAF from waste and residues, bp says.

The Lingen refinery processes the used cooking oil together with crude oil in its existing facilities, with SAF as the end product. Thanks to co-processing, bp can continue to operate the existing plant with some modifications and extensions while also making a direct contribution to decarbonization.

Meanwhile, Marathon is currently in the permitting process for the conversion of its Martinez, California, facility to renewable fuels production. The permitting process includes discussion of possible future uses, and SAF is part of that discussion, a Marathon spokesperson says.

SAF offtake agreements

The expanded interest in using SAF over the past several years has been driven in large part by major play-

ers in the aviation industry, including airlines, aircraft manufacturers, gas-turbine engine makers, international shipping companies and others. According to the International Air Transport Association (IATA; Montreal, Que., Canada; www.iata.org), approximately 100 million liters of SAF were produced in 2021, and about 5 billion liters of SAF production annually are projected by 2025. Twenty new fuel offtake agreements were made during 2021 alone, and 61 forward-purchase agreements totaling 25.8 billion liters currently exist as of April 2022, according to ICAO. Virtually all major airlines have SAF purchasing agreements in place, including United, American, Delta, Southwest, Jet Blue, Alaska Airlines, FedEx, DHL, Luftansa, Qantas, KLM and others.

As one example, bp is to supply DHL Express with sustainable aviation fuel until 2026 as part of a new strategic collaboration with the global logistics company. The bp agreement is one of two deals comprising the largest SAF deals in aviation to date, with a combined volume of more than 800 million liters of SAF. The other supplier, entering in to separate agreement with DHL and making up the total volume, is Neste.

In its Sustainability Roadmap, Deutsche Post DHL Group has committed to using 30% of SAF blending for all air transport by 2030. bp will provide SAF produced from waste oils. Such SAF from wastes and residues can provide greenhouse gas emission reductions of up to 80% over its lifecycle compared with the conventional jet fuel it replaces, thereby reducing DHL's carbon footprint, DHL says. DHL Express transports more than 480 million documents and packages annually across its global network of 220 countries and territories.

Another example of a prominent offtake agreement came as part of the investment agreement between Honeywell and Alder Fuels. United is committing to purchase 1.5 billion gallons of SAF from Alder when produced according to its requirements. United's purchase agreement is said to be the largest publicly announced SAF agreement in aviation history.

In December 2021, Austrian fuel maker OMV and Austrian Airlines (AUA) announced the production and use of regional SAF in Austria. The two companies agreed on the production and fueling of 1,500 metric tons of SAF in 2022.

The sustainable fuel is produced at the OMV Schwechat Refinery by co-processing Austrian used cooking oil in the fuel production process. This approach makes the entire production chain as regional as possible and keeps transport routes to a minimum. Compared to conventional kerosene, SAF makes for a CO_2 reduction of more than 80% over the entire lifecycle. With the direct pipeline connection to the Vienna International Airport, SAF was slated to be available for fueling Austrian Airlines aircraft as of March 2022. ■

Scott Jenkins

Focus on Solids Handling

This bag slitter eliminates dust and reduces waste

The MINILux (photo) is an automated food-grade bag slitter constructed to U.S. Food and Drug Admin. (FDA) standards with self-contained dust collection and recovery. The MINILux is said to recover 1.5–2% more product at a rate 1.8 to 2 times faster than a single bag-dump station. Facilitating a healthy, safe and hygienic working environment by recovering both airborne and trailing product, it also reduces waste and boosts profits. Capable of opening up to six 25-kg bags per minute, the MINILux combines conveying, slitting, emptying, integral dust filtering and empty bag compaction in one system. It features multiple clean-out access points for easy cleanability to ensure allergens and pathogens do not enter the food chain. — *Luxme International Ltd., Brossard, Que., Canada*
www.luxme.com

Luxme International

This system empties bagged powders safely

The AFC Dump Clean EX bag break station (photo) permits powders to be automatically transferred from bags, sacks, drums and other containers into storage or into the process without allowing fine particles to escape into the workplace. The station continuously draws dust inside the unit before it can become airborne, virtually eliminating the fuel source from the explosive environment along with the potential for an explosive incident. The AFC Dump Clean EX features an upgraded hazardous-location motor with companion electrical components that meet National Electrical Code standards for transferring Class I, Division II hazardous materials, plus an explosion-proof NEMA 7/9 control panel enclosure, and anti-static filter media to prevent electrostatic discharge. — *Automated Flexible Conveyor, Clifton, N.J.*
www.afcspiralfeeder.com

Automated Flexible Conveyor

Level switches for packed powder applications

The GJ Level Switch (photo) can operate as high or low point level indicators for bulk solids that tend to pack or bridge easily. The GJ detector operates successfully with consistent results on applications such as chemical powders, minerals and many other granulated materials. These level switches measure dry bulk solids ranging from less than 15.0 to greater than 60 lb/ft^3. The level detectors are factory calibrated and do not require any field calibration before installation. There are no moving parts, no gaskets or seals to deteriorate. They are approved for Class I, Groups C & D; Class II, Groups E, F & G; and Class III services, as well as CSA C/USA approved. — *Automation Products, Inc. – Dynatrol Div., Houston*
www.automation.com

Automation Products

This conveyor bag-dump station is mobile

A new sanitary, mobile tilt-down flexible screw conveyor with integral bag-dump station and compactor (photo) allows the transfer of material manually dumped from handheld bags into elevated process equipment, and the disposal of empty bags, dust-free. Mounted on a mobile frame with locking casters and a fold-down step, the bag-dump station is secured to the floor hopper with quick-release clamps, and features a gasketed bag-disposal chute through the side wall of the hopper hood, allowing the operator to pass empty bags directly into the bag compactor. Dust generated from both dumping and compaction is drawn onto the system's two cartridge filters. An automatic reverse-pulse filter cleaning system releases short blasts of compressed air inside the filters at timed intervals. This causes any dust built up on the outer surfaces to fall into the hopper, conserving useable product. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

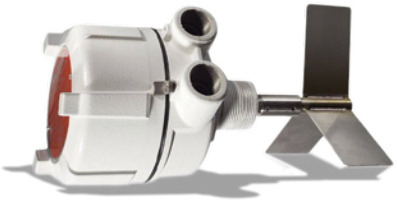
This system provides feeding and mixing in hazardous areas

The Turbo Compact Mixing (TCM) module (photo, p. 22) meets ATEX requirements for operation in hazardous environments. The TCM is suitable for installation in ATEX zone 20 internal and zones 21 and 22 ex-

Flexicon

Gericke USA

Volkmann USA



BinMaster

Haver & Boecker Niagara

Heumann Environmental Company

ternal in areas where an explosive atmosphere with a cloud of combustible dust is likely to occur or remain present continuously or for long periods of time during normal operation. The explosion-safe TCM integrates continuous mixing with the company's gravimetric loss-in-weight (LIW) inline feeder to automatically meter precise amounts of dry material into the companion continuous mixer for fast, gentle mixing on a compact footprint. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickegroup.com

Inert explosion-proof conveying system

The INEX-PPC pneumatic vacuum conveying system (photo) features a patented approach that allows powders and other bulk materials to be safely conveyed in hazardous environments without concern for explosions. Explosion-proof by design, the INEX-PPC introduces nitrogen or other inert gas to create an inert atmosphere within the vacuum receiver for safe transfer into ATEX Zone 0 areas where an explosive mixture is present continuously or for long periods of time. The system conveys dry or semi-wet materials from storage into reactors, mixers or other vessels located in ATEX environments. The sealed, enclosed system includes stainless-steel construction with a polished interior and minimal connections for safe, smooth gas purging and fast disassembly without tools for easy cleaning. — *Volkmann USA, Bristol, Pa.*
www.volkmannusa.com

A rotary paddle switch for bulk storage

The BMR-100 rotary sensor (photo) offers simple, electromechanical measurement for ordinary storage and processing operations. It is generally wired to a light or horn to alert to high or empty levels. The level switch works with solid materials with a bulk density of 2 to more than 100 lb/ft^3. This versatile level indicator is offered with a wide range of accessories. There are 19 different paddles for light, medium and heavy bulk-solid materials. Collapsible paddles are convenient for installation without entering the vessel. Point-level alarm panels display vessel level conditions via a blinking light and an audible alarm with up to 24-level indicator stations. — *BinMaster, Lincoln, Neb.*
www.binmaster.com

Vibrating screen with simplified maintenance

This company has added new features to its Niagara F-Class vibrating screen (photo) for simplified maintenance combined with maximum performance and longevity. The new design retains the technical benefits of the original F-Class, such as improving performance in material stratification and reducing blinding and pegging. The vibrating screen is now primarily manufactured with vibration-resistant lockbolts instead of the traditional welding used in previous designs. Lockbolts are more effective at maintaining structural integrity during the demanding load-bearing, high-vibration operation of a vibrating screen, while making maintenance more convenient, safer and cost-effective. — *Haver & Boecker Niagara, St. Catherines, Ont., Canada*
www.haverniagara.com

Software service streamlines industrial cyclone design

Last September, this company launched a secure cloud-based software service that enables users to design and build cyclones. Developed by subsidiary Heumann Software Company, the High Efficiency Cyclone Calculator — or HECyclone for short — represents the first of a suite of secure and validated software services for companies whose operations incorporate reverse flow cyclones. HECyclone provides precise cyclone performance modeling — from the prediction of cyclone pressure drop, to quantifying the impact that dimensional changes can have on the separation efficiency over the full range of particle sizes, to calculating overall total collection efficiency from a known particulate size distribution (photo). Through its easy-to-use interface, users can select a cyclone model and provide the conditions for its use. — *Heumann Environmental Company LLC, Jeffersonville, Ind.*
www.heumannenviro.com

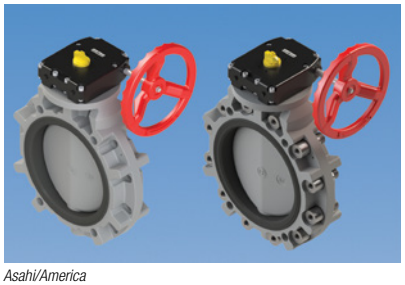
Gerald Ondrey

New Products

Dräger

This gas detector finds volatile substances at very low volumes

The new X-pid gas detector (photo) quickly detects volatile organic substances, such as benzene, even at extremely low concentrations. To determine the concentration of certain hazardous substances, the device combines two measuring modes, optimally supporting strategies for measuring in hazardous areas or confined spaces. It builds upon its predecessor with the addition of a search measuring mode, which allows for continuous monitoring for photoionization-detection (PID) sensitive compounds prior to using the analysis mode for a more specific analysis. The sensor unit can be controlled via an explosion-protected smartphone by means of a mobile application. — *Dräger, Inc., Houston*
www.draeger.com



Asahi/America

This family of CPVC butterfly valves has been expanded

This company has added two new sizes (10- and 12-in.) to its Type-57P family of chlorinated polyvinyl chloride (CPVC) butterfly valves (photo). The new models are well suited for facilities where large-diameter CPVC body and disc butterfly valves are needed due to elevated water temperatures. The valves are available with ANSI wafer-style connection or with 316 stainless-steel lug inserts. Additionally, Type-57P CPVC valves can be actuated both electrically and pneumatically, and various manual accessories can be installed. — *Asahi/America, Lawrence, Mass.*
www.asahi-america.com

PureAir Filtration

This absorbent media can prevent carbon-bed fires

This company has launched Sulphasorb 2 (photo), a new activated alumina and carbon chemical-adsorbent media that reduces the risk of carbon-bed fires in paper mills and other critical locations. This upgraded chemisorbent media was designed in response to fire concerns at paper mills where corrosive gases are present. Serious explosions and fires have happened in paper mills over the years due to not properly maintaining air purification systems or following the right procedures to mitigate risk. Sulphasorb 2 dramatically reduces the risk of fire by using a proprietary caustic blend impregnated on a mixture of activated alumina and carbon, says the manufacturer. — *PureAir Filtration, LLC, Atlanta, Ga.*
www.pureairfiltration.com

A low-power CH_4 sensor with digital and analog capabilities

FlameIR-ME1 is a new methane sensor that uses a solid-state LED optical technology and operates with a low energy consumption. The sensor is compatible with battery-powered operation, allowing the sensor to be used in a wide variety of applications, including wirelessly connected equipment. The device includes altitude-pressure compensation, real-time temperature correction and the ability provide either analog or digital methane measurements. The FlameIR-ME1 also features a built-in zero-tracking function to maintain CH_4 measurement accuracy over the lifetime of the product. The sensor can be zeroed at power-on, and also periodically for applications that are permanently powered. Limits can be set on the amount of zero movement allowed, with the status flag used to indicate large changes from the initial calibration setting. Typical measurement accuracy is 0.01%. — *Gas Sensing Solutions, Cumbernauld, U.K.*
www.gassensing.co.uk

Val-Matic

Use these plug valves with slurries and gritty media

This company's Cam-Centric plug valves (photo) feature 100% port, which makes them a suitable choice for applications where slurries, grit or solids are present. The valves' eccentric action allows the plug to rotate and lift out of its seated position, thus minimizing rubbing or scraping. Features such as a heavy-duty, fully rubber-encapsulated plug, welded nickel seat, grit-seals and V-Type packing provide reliable operation. The valves are available with a variety of materials options, including fusion-bonded epoxy, rubber lining and glass-lining coatings. — *Val-Matic Corp., Elmhurst, Ill.*
www.valmatic.com

An ammonia leak-detection system for process refrigeration

The Chillgard 5000 NH_3 monitoring system (photo) features a sophisticated design with photoacoustic infrared (PAIR) sensors that provide an easy-to-install, highly reliable gas-detection solution specifically for ammonia. The systems are compliant with ANSI/International Institute of Ammonia Research (IIAR) and EN378 requirements, making them useful in a number of industries that require refrigeration or freezers. PAIR sensing offers the earliest level of detection of NH_3 leaks for plant safety. Unaffected by temperature and humidity swings, PAIR sensors operate for months with virtually zero drift, says the company. In the event of an NH_3 gas leak, the Chillgard 5000 System provides a clear visual and loud audible signal to indicate that there is a potentially dangerous and expensive leak. In addition, the Chillgard 5000 Remote Display provides gas-monitor information before room entry where potentially hazardous gas levels may exist. — *MSA Safety, Inc., Cranberry Township, Pa.*

www.msasafety.com

A new generation of centrifugal mixers for 3D printing materials

Smart DAC centrifugal mixers (photo) feature variable counter-rotation, increased mixing weight (250 g up to 2 kg) and volume (310 mL up to 2.8 L) and allows up to 30 min of mixing time. The mixers feature real-time temperature control, vacuum capability, sensor integration, variable counter-rotation, Industrial Internet of Things (IIoT) compliance, remote control and an auto-programmable cooling system. The Smart DAC's structure also allows mixing from 0 rpm up to maximum speed without the risk of high vibrations, offering a significant advantage when, for example, a light powder is one of the components to be mixed. According to the manufacturer, the Smart DAC is uniquely suited for mixing materials used in 3D printing because it can accurately homogenize and dispense solid powders, biological materials and resins, as well as base materials containing viscous polymers. — *Hauschild GmbH & Co KG, Hamm, Germany*

www.hauschild-speedmixer.com

This line of ball valves has an expanded operating range

This company has expanded its line of high-performance ball valves to include 2.5-, 3- and 4-in. sizes of the 585HP-LF and 585HP-66-LF bronze ball valves (photo) in solder, threaded and press end connections. Designed for commercial and industrial applications, the lead-free and corrosion-resistant 585HP full-port ball valve line allows for simpler installation, adjustability and long service life. The patented, laser-welded construction eliminates the threaded body to body-end connection, allowing for higher operating pressures and an operating temperature up to 250°F. The expanded 585HP line features a reversible handle, which provides flexibility for on-site modifications, a large accessible packing nut and a triple-sealed stem. — *Nibco, Inc., Elkhart, Ind.*

www.nibco.com

These vests keep workers cool in hot situations

The StaCool Vest core body-cooling system (photo) helps workers stay cool and productive in higher-than-ambient temperatures, such as those found in manufacturing plants, utilities, power plants, foundries, near ovens and boilers and more. The vest's micro-thin, highly breathable materials are easy to care for, providing wearers cooling comfort without compromising mobility. With models that can be worn over or under normal clothing (including protective clothing), ThermoPaks in the front and back of the vest provide hours of cooling, and a spare set of ThermoPaks are included with each StaCool Vest to extend cooling time and comfort when the initial set thaws. The vest provides ultimate body core cooling, and a thermal barrier is built in to ensure wearer does not get too cold. — *StaCool Industries, Inc., Lecanto, Fla.*

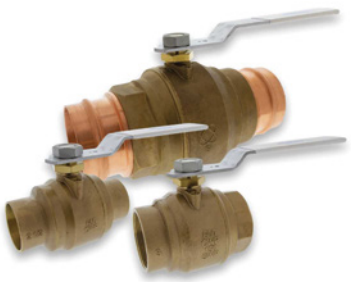
www.stacoolvest.com

Simulate hydraulic systems and prevent waterhammer

The Impulse 9 software suite (photo) was designed to enable engineers to better understand hydraulic systems during deviations from steady state by providing waterhammer and

MSA Safety

Hauschild



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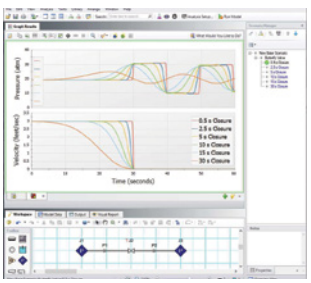

Applied Flow Technology (AFT)

Lugaia USA

Mettler-Toldedo

surge analysis, which helps to mitigate failures and avoid downtime. New features included with the Impulse 9 release include: a redesigned gas-accumulator window to improve usability; the ability to add new features, such as liquid height calculation; improved multi-scenario graphing to compare and animate design alternatives with different time steps; options to convert shear rheometer data for Power Law and Bingham Plastic viscosity models; and the Herschel-Bulkley viscosity model for shear thinning or thickening fluids with a yield stress. — *Applied Flow Technology (AFT), Colorado Springs, Colo.*
www.aft.com

Customized containment solutions for hygienic processes

This company's continuous liner systems (CLS; photo) are designed for single-use applications in hygienic process technologies in cleanrooms. The single-use liners eliminate the need for expensive and time-consuming cleaning processes for hygienic systems and the costly qualification procedures that go with them. For sealing and separating, the CLS uses the patented SafeSeal Closure System, whereby an OEB 5 (<1µg/m^3) containment level can be guaranteed, says the manufacturer. Axial folding enables film lengths of up to 80 m. Fold height and foil length are dependent upon film thickness. The CLS will be exhibited at Interphex (May 24–26) in New York City. — *Lugaia USA, LLC, Ponte Vedra Beach, Fla.*
www.lugaia.com

New meters for pH, conductivity and ion concentration

Developed for a wide range of applications, SevenDirect benchtop meters (photo) provide accurate measurements of almost any sample. The intuitive user interface on the 7-in. touchscreen facilitates the measurement process by avoiding unnecessary steps and focusing on the most important information. On-screen instructions guide users through the calibration process while the integrated help system provides immediate support. The EasyPlace electrode arm ensures precise placement of the sensor. The instruments support Good Laboratory Practice (GLP) compliance by storing timestamps, as well as sample, sensor and user IDs with every measurement. Automatic data transfer to PC or printer minimizes transcription errors. — *Mettler-Toledo, LLC, Columbus, Ohio*
www.mt.com

A complete system for developing emerging foods

Unveiled at Anuga FeedTec trade fair (Cologne, Germany; April 26–29), the Mobile Test Center (MTC; photo, p. 27) for new food applications is now available for rent, purchase or for use on this company's premises. This fully equipped, pilot-scale process line for cell cultivation or fermentation can be individually configured to bridge the gap between laboratory work and demonstration plants. Using the test center, users are able to not only determine parameters ranging from cell viability through mass balance to yield, but also to efficiently design processes and develop a future-proof business model for subsequent commercial production. The MTC provides a new way

For details visit adlinks.chemengonline.com/82581-12


GEA

of delivering proof-of-concept for cellular agriculture, without the need to invest in a full pilot plant to facilitate the process of scaling up to commercial cell-based manufacturing. Instead, users can apply the MTC to study cell cultures and microbes, as well as improve fermentation strategy, modify formulas, alter growth media and ingredients, plus tweak process parameters to increase yield and repeatability. The MTC comprises eight industry-approved, food-grade technologies, including multifunctional fermenters or bioreactors, as well as equipment for mixing, heat treatment, homogenization, separation and filtration. — *GEA AG, Düsseldorf, Germany*

www.gea.com

An expanded series of smart Roots pumps

The new line of Roots pumps from the HiLobe series (photo) cover a wide


Pfeiffer Vacuum

range of applications that require large chambers to be evacuated rapidly. These new Roots pumps handle a wide range of nominal pumping speeds up to 13,600 m^3/h. With their powerful drive concept, they shorten pump-down times by around 20% compared to conventional Roots pumps. Rapid evacuation also saves costs and increases the efficiency of production systems. The use of energy-efficient drives and the optimized rotor geometries reduce energy costs by more than 50% compared to conventional Roots pumps, says the company. The pumps are hermetically sealed from the atmosphere and have a maximum integral leak rate of 1×10^{-6} Pa m^3/s. Dynamic seals are eliminated, thus making maintenance necessary only every four years. — *Pfeiffer Vacuum GmbH, Asslar, Germany*

www.pfeiffer-vacuum.com

A trailer support for busy loading docks

The Ground Mounted Trailer Support (GMTS; photo) is a new hands-free trailer-support system. The new support is permanently positioned in the trailer docking area in its retracted state. When a trailer has been docked and secured, the GMTS can be activated from inside the loading dock area, rising to support the trailer from below, during loading/offloading. The GMTS is built for the busy dock environment where a worker in the yard would be at risk from dock traffic. Unlike most trailer support options, the GMTS is not manually deployed by a dockworker, but is operated safely from inside the dock area, eliminating risk and saving time. — *Ideal Warehouse Innovations, Inc., Toronto, Ont., Canada*


Ideal Warehouse Innovations

www.idealwarehouse.com

Mary Page Bailey and Gerald Ondrey

Physical Gas-Separation Methods

Department Editor: Scott Jenkins

Industrial gases are critical for a wide range of applications throughout the chemical process industries (CPI). Many of these gases must be separated from others, such as nitrogen from air, or hydrogen from natural gas using physical gas-separation techniques that include membrane separation, catalytic and adsorption processes, cryogenic distillation, and other technologies. A few common methods are discussed here.

Membrane separation

Membrane separation uses hollow-fiber membranes to separate nitrogen from oxygen (Figure 1). Membrane technology is commonly used when purity requirements are not stringent. Within the membrane system, many thousands of hollow fibers are placed in a housing and compressed air is supplied to one end. The fiber wall is permeable to gases, but the diffusion rate across the fiber wall varies according to the type of gas. For air, oxygen, carbon dioxide, argon and other trace contaminants pass through the wall at a faster rate than nitrogen, and are vented. Nitrogen exits the membrane system at a typical purity of greater than 95%. Users can adjust the flow through the system to vary the purity achieved by a membrane-based system. The advantage of a membrane-based system is there are no moving parts, but outlet purity may vary with flowrate.

Pressure-swing adsorption

Pressure-swing adsorption (PSA) and vacuum pressure-swing adsorption (VPSA) are used in situations requiring higher purity. When separation of impurities in the high parts-per-million (ppm) level is required, as opposed to separation of impurities at the percentage level, PSA is an option (Figure 2). PSA systems are typically used as pre-purification of gases entering a cryogenic process and for the purification of hydrogen. VPSA technology is used for on-site float-glass production and medical-grade oxygen.

PSA systems consist of pairs of vessels operating in parallel, or they can be designed in configurations with multiple vessels in series. Each vessel is packed with adsorption media, such as carbon molecular sieves, zeolites and charcoal. Feed gas to be purified passes through one or more vessels operating at pressures typically greater than 100 psig. Impurities within the feed-gas stream are physically adsorbed (physisorption) onto the surface of the media by Van der Waals forces (weak bonds created by short-range electrostatic interactions among molecular dipoles). PSA systems work by taking advantage of differing adsorption behavior at different pressures and temperatures. Adsorption sites are occupied by impurity molecules, while the desired gas passes through the media. Capacity for each impurity varies based on the media selection, often determined by the pore size. As impurity molecules break through the PSA vessels, the media requires regeneration to remove the adsorbed impurities. Within a PSA system, the vessel is isolated and the gas is rapidly vented to atmospheric pressure, which releases the trapped impurities. The vessel is then re-pressurized and is ready for more feed gas. This regeneration may be completed at a cycle time of minutes to hours. For the separation of nitrogen or oxygen from air, the cycle is typically short.

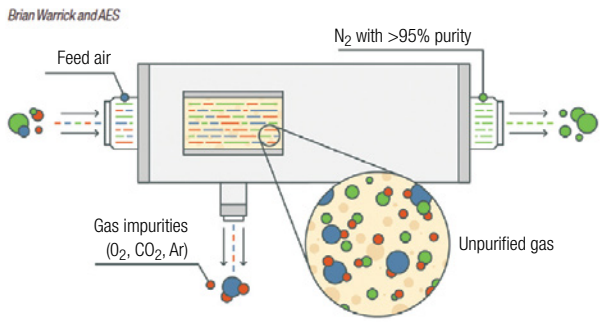

FIGURE 1. Membrane separation methods are used in applications where purity requirements are not especially stringent

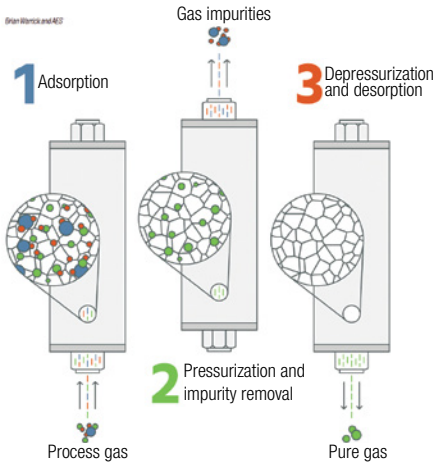

FIGURE 2. Pressure-swing adsorption is an option when the separation of impurities needs to reach the high parts-per-million level

Cryogenic distillation

When low-PPM-level gas purity is required, cryogenic distillation is typically used. Cryogenic processes are based on the physical separation of gases relative to their boiling points. Many gases may be cryogenically separated, but air separation is described here. Compressed air is chilled and then passed through a molecular sieve bed to remove moisture, hydrocarbons and carbon dioxide before entering the distillation column. Gas entering the column is cooled to cryogenic temperatures against outflowing gases. To maintain the balance of refrigeration needed to sustain the process, an expansion turbine is often used. The air travels up the column through a series of trays against reflux liquid that is cascading down the column. Separation of the gases occurs because of different boiling temperatures. Nitrogen at 99.999% purity or greater may be supplied directly as vapor, or liquified for cryogenic delivery. Impurities within the nitrogen typically include carbon monoxide and hydrogen, which have a similar or lower boiling point. ■

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2. Keller, T. and Shahani, G., PSA Technology: Beyond Hydrogen Purification, *Chem. Eng.*, January 2016, pp. 50–53.

Should the Doctor Believe a Flowmeter?

Henry Kister shares lessons learned from troubleshooting distillation towers

Many cooling-water systems do not have flowmeters. This is a tale about a cooling-water flowmeter that made a difference.

As a startup superintendent at ICI Australia in the late 1970s, the author was in charge of starting up a new unit in the olefins plant that produced polymer-grade propylene. The main equipment was a C3 splitter column, which at the time was the biggest tower in Australia. It is still in operation today, and can be seen as one lands at Sydney Kingsford Smith Airport. The auxiliaries were a reboiler heated by waste heat from the olefins quench-water system, a water-cooled condenser, and a reflux drum. Due to the very high cooling load, a new cooling-water system was added to service the new unit alone, mostly the C3 splitter condenser. The cooling tower was some distance away from the unit, and the large cooling-water pipes were mostly underground to avoid the need of a pipe rack. The equipment was installed, and the author was in the process of commissioning and testing the unit, well before hydrocarbons were introduced.

The author started up the cooling-water system. The startup was smooth and uneventful. Everything was fine, water flowed over the cooling tower, the pump was pumping with a discharge pressure close to design. As the process side was not commissioned yet, no heat was exchanged.

The author walked around, closely watching the system when he noticed the cooling-water flowmeter (Figure 1) reading zero. The flowmeter was in a horizontal section of pipe, with ample pipe diameters before and after to give a reliable reading. The dial was actually hitting the stop pin below the zero mark. The author called the plant instrument foreman, who checked the transmitter.

"This worthless transmitter is kaput." He said (using another word for "kaput"). "All that Engineering have been giving us in this plant is junk (again, using another word for "junk"). Why don't you tell Engineering to provide us with instruments that work?"

This statement was true. Many of the instruments that were supplied were inoperative. I passed the message to Alan, the Engineering instrument engineer.

"Again? Our apologies. Let me look into it."

A couple of hours later he returned. "I checked the transmitter. There is nothing wrong with it. It works."

"So why is it reading zero? The pump is pumping flat out, the water flowing, and had the transmitter been any good, it would not read zero."

"Are you sure your cooling water is not going backwards?" he asked.

I almost choked, then stared right at him.

"Alan, if anybody else came up with this nonsense, I would have thrown him out of this door. But in your case, I have a lot of respect for your expertise, which incidentally, with this kind of comment I am about to lose. But just for old times sake, I will get this nonsense out of your head."

"How?" he asked

"Let's go." We climbed up the condenser platform. I pointed at the butterfly valve at the condenser outlet. "I will shut the valve and open the 1-in. vent valve (Figure 1). What you will see is a water jet shooting up 30 ft in the air, which will disprove your nonsense idea."

"Good deal," he said.

I shut the butterfly valve, then opened the vent. A water jet shot up 30 ft in the air, just like I expected. As I was getting ready to shut the valve, the jet plunged, and plunged, until it stopped. I shook my head in disbelief.

"This is why the needle was hitting the stop pin. It was reading negative and tried to tell us something," he said.

I reopened the butterfly valve, then repeated the test. Just in case I was dreaming. The same happened again. It was not a dream.

"I am taking it back, Alan. My respect to your expertise has doubled. This is an amazing catch."

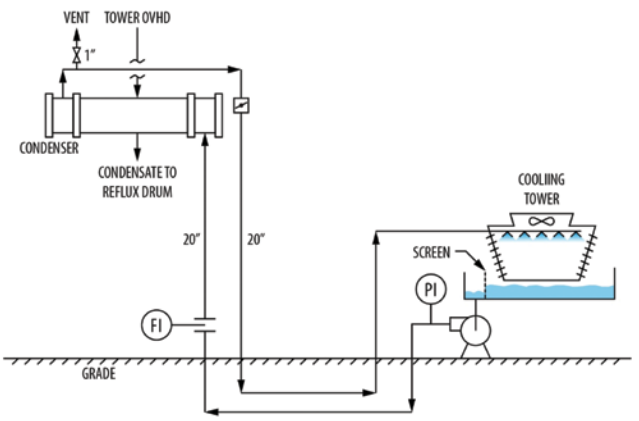

FIGURE 1. This diagram shows the cooling water system for the propylene purification system as planned

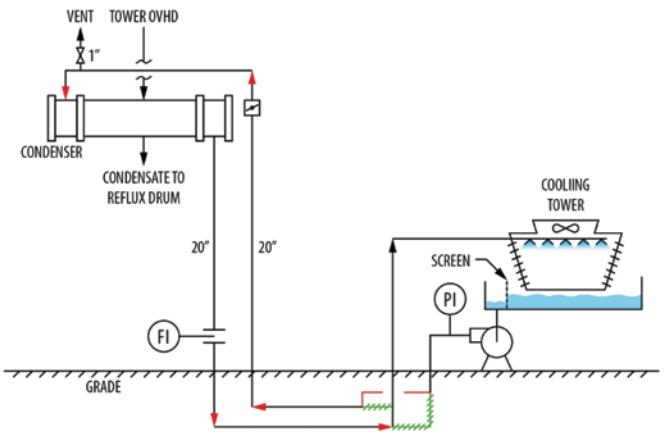

FIGURE 2. This diagram shows the cooling water system in the propylene purification system as installed

The author instructed removing the dirt that covered the underground pipes. Sure enough, there was an incorrect pipe connection underground (Figure 2) that was overlooked by the construction inspectors. As a result, the cooling water flowed backwards through the condensers and the meter. Being underground, no one suspected this. Fortunately, this issue was identified before hydrocarbons were introduced. It was the one flowmeter and a top-notch instrument engineer that made all the difference.

The takeaway: A good doctor does not disbelieve an instrument. It may be trying to tell you something. You do not need to trust it, but listen to it. Always thoroughly check out suspicious readings. ■

Edited by Dorothy Lozowski

About the Tower Doctor

"The Tower Doctor" is the honorary title bestowed upon the author of this article in 2002 by Richard Darton, professor of Engineering in Oxford University and chair of the European Distillation Network. "When a tower is not well," says Darton, "people call Henry to diagnose the illness and find a remedy. He arrives with his doctor's bag, examines the patient-tower, measures its temperature and pulse, gets radiography to get an inside look. Then comes his diagnosis and cure. Towers treated by Henry mostly get better very quickly."

Being son to two medical doctors who were blessed with phenomenal diagnosis ability, the author aspired to live up to this special honorary title. Like with medical doctors, some illnesses were a struggle to diagnose, others were easier. All were exciting. This column will reminisce through some of the more entertaining cases. They may not have seemed entertaining at the time, but looking back at them, they leave unforgettable memories and raise a smile or two. One great aspect of being a tower doctor, one gets to work with and learn from some of the greatest engineers and operators that contributed so much to the chemical industry. We hope that this column can pass some of the fun, excitement and lessons learned to future troubleshooters and tower doctors.

Author

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For more on distillation, see Kister, H. Z., Gas Trapping can Unsettle Distillation Columns, *Chem. Eng.*, pp. 47–55, April 2022.

Vent Away Condensate Pump Frustrations In A Flash

The guidance provided here can help to mitigate problems occurring in pumping systems used for condensate recovery

James R. Risko
TLV Corp.

IN BRIEF

Condensate recovery is crucial to energy reduction and water conservation in a steam-using plant. It reduces effluent discharge and treatment requirements, as well as the chemicals and heating costs associated with preparing raw makeup water. Furthermore, having a greater percentage of high-quality condensate for boiler feed helps to reduce corrosion in the piping system [*1*, *2*]. Even with relatively simple condensate pumping systems like the one shown in Figure 1, condensate recovery can sometimes create complex challenges for plants.

A problematic pumping station, such as the one shown in Figure 2, is a result that may be all too common in some steam systems and can occur due to leaking seals or pump cavitation, ultimately causing condensate to overflow. Are all such instances due to normal wear, or have some been caused by poor design or insufficient system maintenance? Experience demonstrates that many comparable reliability issues can be avoided with improved design and system maintenance practices, but first it is necessary to identify probable causes and implement suitable mitigation action, preferably during the design stage, when possible.

How does cavitation occur?

Cavitation is normally a key factor, and engineers should first understand what causes this phenomenon in order to design around its potential occurrence [*3*, *4*].

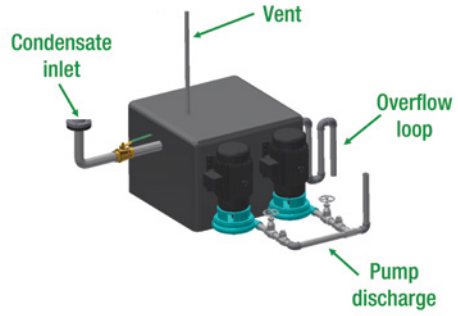

FIGURE 1. A simple condensate pump arrangement includes an inlet, receiver, vent, pumps and overflow loop

FIGURE 2. This pump station exhibits severe spillage, creating a potential safety hazard and source of problems

Figure 3 shows a centrifugal condensate pump that is experiencing cavitation issues. This situation happens when flash steam — formed from the re-vaporization of high-temperature condensate by the suction-side pressure drop — rapidly pushes away liquid volume in the impeller. Condensate is further accelerated by pump rotation, and this combination leads to impeller erosion. As a result, the vapor pockets, which are compressed by liquid flowing through the prop troughs, quickly collapse and cause an on-rush of condensate into the void. This can cause more damage to the impeller and pump seals. Cavitation is typically not a singular event, but rather is ongoing throughout the causal conditions, resulting in capacity reduction or catastrophic failure of the condensate pump itself, or resultant spillage through leaking seals or the overflow.

This leads many engineers to ask how cavitation can be avoided. An understanding of both net positive suction head available ($NPSH_A$) and net positive suction head required ($NPSH_R$) is needed.

$NPSH_A$ is the resultant head at the eye (central point) of a pump's impeller. It is a function of all of the fluid variables acting on the inlet side of the pump. Those include positive head factors, such as pressure created by the inlet height of the condensate

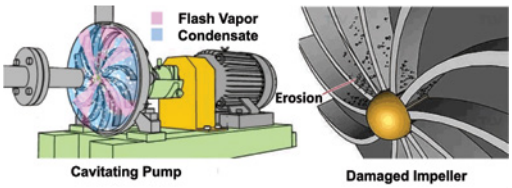

FIGURE 3. As the impeller spins, dynamic increase causes static pressure drop, which begins vaporizing the high-temperature condensate

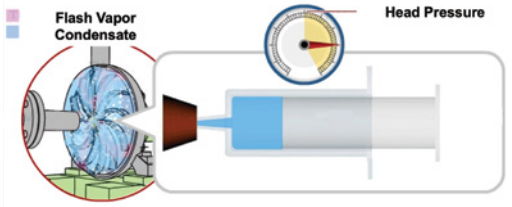

FIGURE 4. High head pressure ($NPSH_A$) mitigates condensate vaporization, maintaining liquid for pumping

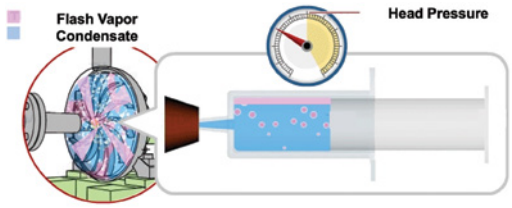

FIGURE 5. When $NPSH_A$ decreases due to high rotation, some liquid flashes into steam, thereby causing cavitation

column over the impeller and the surface pressure acting over that incoming condensate, as well as negative head factors like the vapor pressure of the condensate (how easily the condensate can vaporize) and inlet piping friction loss. Sufficient $NPSH_A$ is important to keep the condensate from vaporizing as it experiences a static pressure drop when the dynamics increase from impeller rotation (Figure 4). Although condensate may be in liquid form entering the impeller, portions can flash into steam vapor, causing cavitation when the $NPSH_A$ head pressure is reduced (Figure 5).

Pump selection

Pump manufacturers normally provide the specific $NPSH_R$ for reliable performance, which requires that the $NPSH_A$ always meets or exceeds the $NPSH_R$ to prevent cavitation [5]. $NPSH_A$ calculations can be relatively simple to perform, and one of the main values needed is the vapor pressure at the expected temperature of the condensate being discharged, as shown in Table 1.

Consider a hypothetical new installation that is designed to pump 210°F condensate from an atmospheric receiver elevated 3 ft above the impeller (Figure 6). The temperature corresponds to a vapor pressure of 14.14 psia in Table 1, and assuming a minimal pressure drop of 0.2 psi for the inlet piping, the $NPSH_A$ can be estimated as 3.83 ft. With $NPSH_A$ known, it is just necessary to check the pump curve to determine if the $NPSH_A$ is suitable for the $NPSH_R$ of the selected model.

Suppose that the proposed pump has performance curves as shown in Figure 7. The pump is rated for 37.5 gal/min at 30 psi total discharge pressure (TDP). Since the TDP curve ends at 25 psi, if the pump resistance is less than 25 psi, it may burn out the motor. It can be seen at point D that this pump has an $NPSH_R$ of 9.5 ft, which is significantly higher than the $NPSH_A$ of 3.83 ft. Although the pump may meet the discharge rate and pressure, it can be expected to cavitate severely due to insufficient head to prevent the entering condensate from flashing as the impeller rotates. Typically, high-$NPSH_R$ pumps tend to operate at high speed (around 3,500 rpm), and lowering the rotation dynamics by using low-speed models (for instance, 1,750 rpm) can reduce the drop in static pressure. Such lower-speed pumps are commonly referred to as "low NPSH" models.

There can be several caveats when selecting low-rpm pumps to avoid cavitation. One is that these models, when selected for a certain TDP, tend to be more sensitive to changes in backpressure or total dynamic head (TDH), and another is that their cost can be substantially higher.

TABLE 1. ABSOLUTE VAPOR PRESSURE OF WATER AT VARIOUS TEMPERATURES [6]

Temperature, °F	Pressure, psia
180	7.52
190	9.35
195	10.40
200	11.54
205	12.78
210	14.14
212	14.71
215	15.61
220	17.20
225	18.93

Given those potential concerns, it can be useful to consider alternative methods to prevent cavitation using lower-cost, high-rpm models or non-electric secondary pressure drainers instead, which are explained later in this article.

Consider a hypothetical electric pump with a curve similar to Figure 7 with insufficient $NPSH_A$. It is clear that the model shown in the pump curves will not be appropriate (since $NPSH_A$ is less than $NPSH_R$), so how can this be improved? When the $NPSH_A$ is insufficient, it is necessary to increase its value to use the high-rpm pump unit, and there are two possible methods to achieve this objective. The first is to increase the fill head by elevating the receiver, and this is often possible when the pump is located at a much lower level than the source of the condensate. The second option is to reduce the condensate temperature.

The example shown in Figure 8 illustrates that just elevating the re-

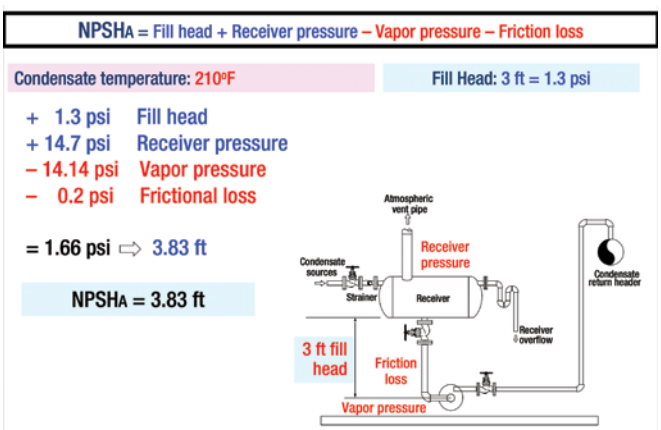

FIGURE 6. The $NPSH_A$ of 3.83 ft is calculated for 210°F condensate with an atmospheric receiver and 3-ft filling height over the center point of the impeller

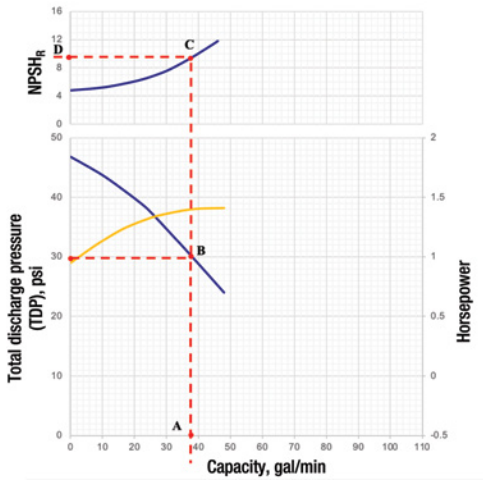

FIGURE 7. The $NPSH_R$ for this pump is 9.5 ft (point D)

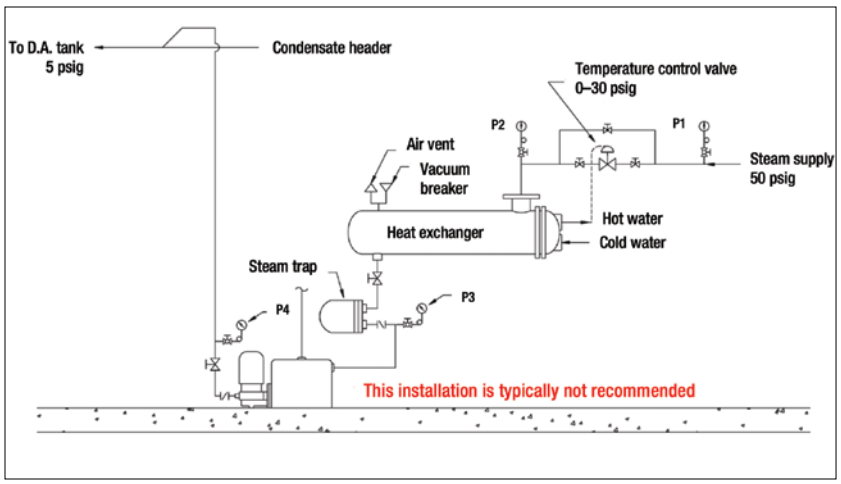

FIGURE 9. This particular design configuration is not recommended because its lack of a flash receiver can have a negative impact

TABLE 2. THE IMPACT OF DECREASING CONDENSATE TEMPERATURE

Condensate temperature reduced to 200°F	
New vapor pressure is 11.54 psia	
Calculation	
+1.3 psi	Fill head
+14.7 psi	Receiver pressure
–11.54 psi	Vapor pressure
–0.2 psi	Frictional loss
= 4.26 psi Corresponds to 9.83 ft $NPSH_A$	

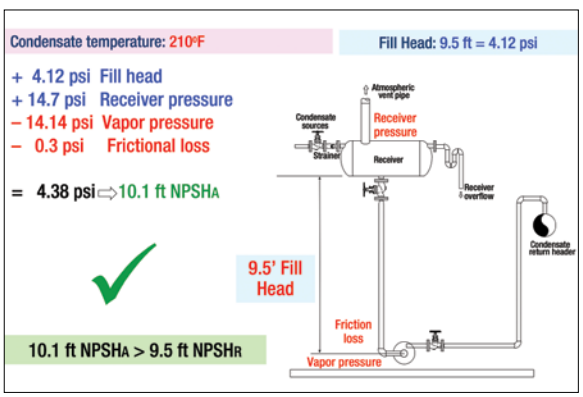

FIGURE 8. Increasing receiver height increases $NPSH_A$

ceiver by 6.5 ft — from 3 ft to 9.5 ft — increases $NPSH_A$ to 10.1 ft, which is more than sufficient for the $NPSH_R$ of 9.5 ft. Alternatively, keeping the receiver elevation at 3 ft, but reducing the condensate temperature by 10°F (from 210 to 200°F) increases $NPSH_A$ to an acceptable value of 9.83 ft, as outlined in Table 2.

Vent problems away

An example of a common application design is shown in Figure 9, with a heat exchanger discharging condensate that flashes when exiting the steam trap into a floor-mounted, electric condensate pump. The drawing is provided with the notice that this installation is typically not recommended. Since the receiver is clearly vented, why is this particular example not recommended? What is the potential cause for this pump to cavitate? This installation is similar to the pump shown in Figure 2 that experienced significant maintenance issues causing spillage. Figure 10 provides clarification about some of the issues with this layout, namely the role of the 1-in. pipe at the top of the installation. Other considerations for Figure 10 include the following:

- The small receiver collects condensate at the pump inlet
- The small vent equalizes internal pressure as water level rises and falls
- Condensate pressure and temperature are increased if flash is not vented before
- An increased temperature results in lower $NPSH_A$, potential cavitation, motor overheating and damage to pump seals

There can be a misconception about the vent found on condensate pump tanks like this floor-mounted example. That vent is sometimes considered by designers to be a flash steam vent, but in actuality, its purpose is to allow balancing of the tank to the atmosphere so that condensate can freely enter and replace the vapor space within the receiver. Commonly, the floor receiver's vent is too small to handle flash steam velocity appropriately — ideally to less than or equal to 50 ft/s, or at a maximum, 70 ft/s. Note that this selection depends on actual site procedures and recommendations from a knowledgeable engineer [*7*, *8*]. A correctly sized vessel should be added to the system to vent the flash steam prior to entry into the condensate pump receiver (Figure 11).

As can be seen in Figure 9, there is no separate flash vessel, and the hot condensate is discharged directly into the floor-mounted receiver. There are several issues with this approach — the first being elevated condensate temperatures and the second relates to insufficient filling

TABLE 3. VENT SIZE RESULTS FROM SELECTED ELECTRIC PUMP MANUFACTURERS

Pump manufacturer	Vent size, in.	Velocity, ft/s	Pressure drop over 12-ft pipe length, psi	Steam temperature, °F
1	1.25	715	4.8	227
2	1.5	526	2.1	219
3	2	319	0.6	214

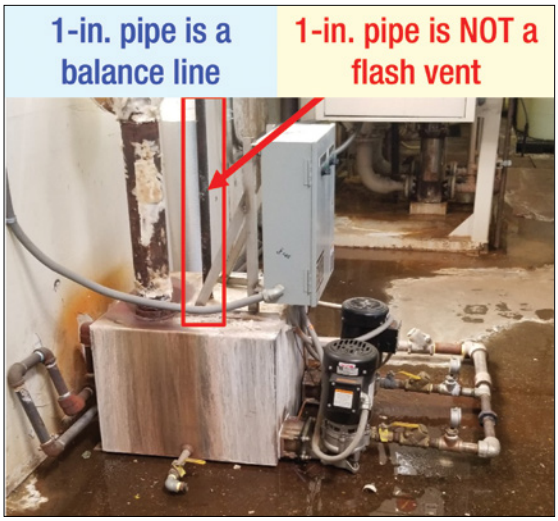

FIGURE 10. The 1-in. vent line is for balancing vapor to allow liquid entry into the receiver. It is generally too small to be used as a primary flash steam vent

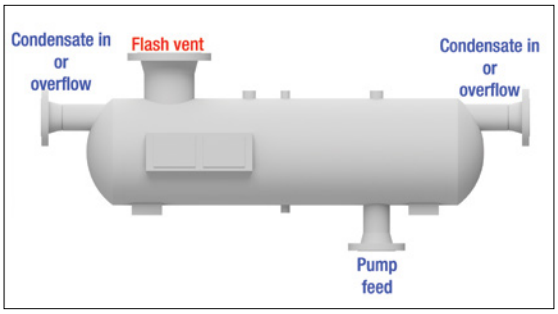

FIGURE 11. Implementation of a properly designed flash receiver is key to reliable condensate pump operation

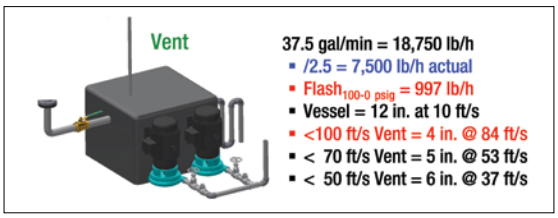

FIGURE 12. An appropriate flash-vent line size for the actual flow-rate would be 5 or 6 in. [*8*]

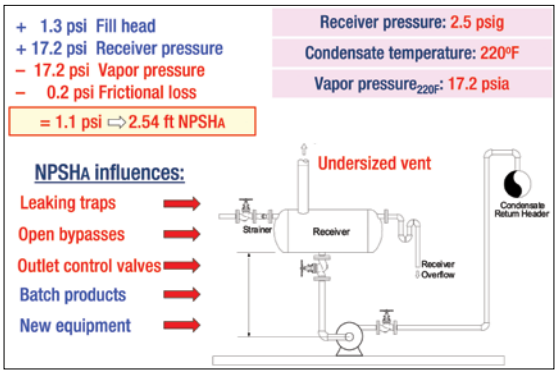

FIGURE 13. These five factors can decrease $NPSH_A$

head. This can cause pump damage and spillage of hot condensate to the grade, which creates potential for burns, slippage and freezing (if outdoors).

Consider the setup shown in Figure 12 for a pump selected to discharge 7,500 lb/h actual load from condensate formed with 100 psig steam. The flash steam amount generated can be as high as 997 lb/h. For this application, even a 4-in. vent would be too small and shows potential exit velocity of 84 ft/s. A 5-in. vent with 53 ft/s velocity might be acceptable for some engineers, but a 5-in pipe is an unusual size. As a result, a 6-in. vent pipe with 37 ft/s velocity would most likely be recommended.

Now, we can reference Table 3, which shows the provided vent size on floor receivers from three different condensate pump manufacturers, along with the estimated velocities for this amount of flash steam — note that the receiver vent sizes from all three pump manufacturers are too small to handle flash. Using the pump's floor receiver as a flash vessel could result in vent velocity as high as 715 ft/s, which is more than 10 times the recommended maximum exit speed. In addition, a pressure drop as high as 4.8 psi is estimated over a hypothetical 12-ft equivalent exit pipe length. The pressure drop builds up pressure in the receiver, and that can also have a detrimental effect on the $NPSH_A$.

Consider the example shown in Figure 13 with an elevated pressure of 2.5 psig, which corresponds to a 220°F condensate temperature. Since the receiver pressure is no longer atmospheric, it is possible that the temperature can remain elevated. Notice how the $NPSH_A$ has decreased to 2.54 ft, even lower than the original 3.83 ft previously reviewed in Figure 6. Table 3 also shows that a vent pressure drop of just 2.1 psi can pressurize the receiver to maintain nearly the same temperature at 219°F. This provides evidence of the need for a separate, properly sized flash vessel and vent.

Leaking traps, open bypass valves and blow-through of live steam through outlet control valves can further elevate pressure and temperature, severely impacting $NPSH_A$. Adding batch loads or new equipment not only requires greater pump-discharge rates, but also increases the flash steam amount that must be vented from the system. All of these factors can affect the pressure drop through a vent that is undersized for the additional load (as seen in Figure 13). Mitigation strategies to limit $NPSH_A$ reduction are described below:

- Maintain a healthy steam-trap population
- Close open bypasses
- Mitigate blowthrough on outlet control valves
- Check flash-receiver suitability for added condensate loads
- Install upstream flash tank or knockout pot
  - Flash steam velocity should be ≤ 10 ft/s
  - Flash vent should be ≤ 70 ft/s

Head off problems

Consider that the original problematic pump with an undersized vent could pressurize to 2.5 psig. Notice

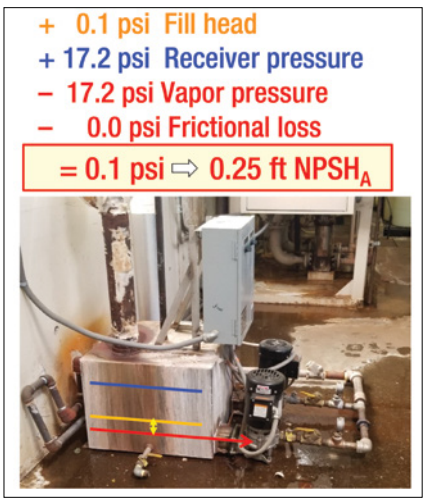

FIGURE 14. There is virtually no fill head on pumps with floor-mounted receivers

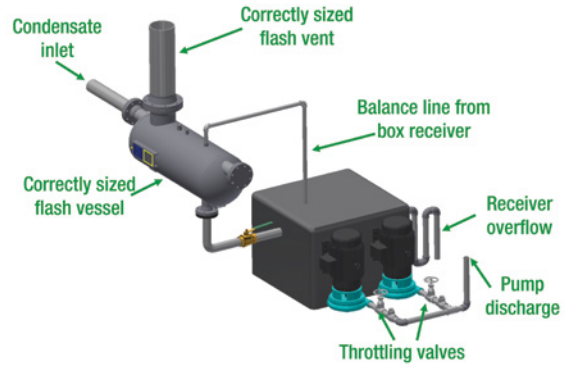

FIGURE 15. A flash vessel reduces condensate temperature and mitigates pressure buildup in the pump receiver

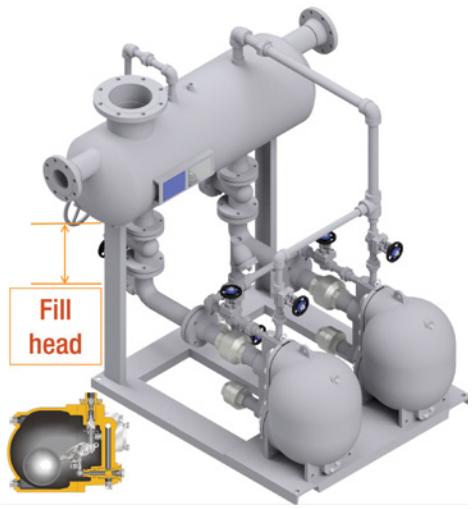

FIGURE 16. Non-electric pumps do not cavitate, but still require flash vessels for proper operation

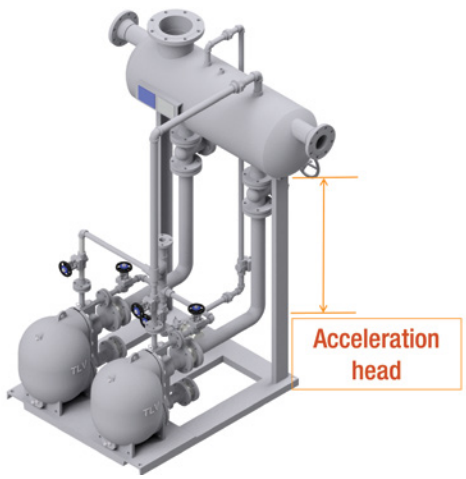

FIGURE 17. Elevating the receiver of non-electric pumps can increase capacity by filling the pump body quickly

the red, orange and blue lines displayed on the receiver in Figure 14. The blue line represents a high-level trigger point that alerts the pumps to operate, and the orange line represents a low-level trigger to stop pumping and thereby prevent losing the water seal over the pumps. Then, note the distance between the orange and red lines. This low-level water height is the vertical head used to calculate $NPSH_A$. As such, floor pumps without a flash tank can pressurize and have a low $NPSH_A$.

There is so little fill head available (approximately 0.1 psi) to provide ample $NPSH_A$ to the pumps. Is it any wonder why these pumps experience issues whenever the condensate temperature is near-to-steam? This pump needs a vapor pressure of 10.68 psia from a non-flashing condensate temperature of 196°F to avoid cavitation, but unless the load is extremely low (for cooling), it is unlikely, due to the undersized vent line.

Reliable system design requires key components, proper elevation, minimal leaked live steam infiltration, good flashing and effective venting, as seen in Figure 15. To mitigate cavitation, condensate pumps should first have the flash steam effectively handled in a properly sized flash vessel, then receive condensate from an appropriate height to provide ample $NPSH_A$.

Non-electric options

Non-electric secondary pressure drainers can be used in lieu of electric pumps. Figure 16 shows an example of a Type 1 secondary pressure drainer (SPD-1) that can provide effective condensate recovery without the use of electrical components [*9*,*10*,*11*]. They are mechanical pumps that use pressurized steam or air to discharge a certain displacement volume of condensate into the return header.

With no impellers to rotate and cause flashing, it is not possible for SPD-1 devices to cavitate during pump operation. Even so, for proper system performance, they do require a separate receiver as part of their installation to enable flashing of high-temperature condensate prior to pump entry. When properly designed, SPDs can provide a significant reliability improvement over electric pumping systems.

Although cavitation is not a concern with an SPD-1 system, there can be a benefit to installing its flash receiver at a higher elevation. This accelerates condensate flow into the pump and increases its capacity compared to the same unit if its tank were situated at a lower level, as seen in Figure 17.

The sizing and overall design of the flash tank/receiver, flash vent and balance line are also key to support reliable SPD-1 operation, so it is recommended to consult with the respective manufacturer of electric or non-electric pumps for design recommendations relative to their systems and in accordance with applicable recognized standards.

Turn flash into cash

There is a great deal of readily available information relating to the design of pressurized flash-recovery systems. These provide a great benefit, because often as much as 10% of flash steam can be recovered and used for low-pressure purposes. One key dependency for flash recovery to be valuable is a definite need for use of this supplemental steam elsewhere so that it reduces boiler load. If the boiler demand is not reduced, then the alleged savings do not materialize.

Another key dependency for implementation is to understand whether the elevated backpressure limits the process equipment performance or increases maintenance costs. If equipment performance or reliability are hindered, then those issues may preclude its use.

These questions can be reviewed by knowledgeable engineers who can perform appropriate design and steam-balance analyses to confirm if the anticipated benefits can be achieved.

However, even if it is not possible to install a pressurized flash-recovery system to use flash steam elsewhere, there is still the possibility to recover valuable portions of the flash that would otherwise be wasted to atmosphere.

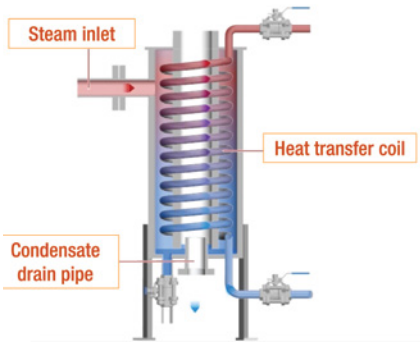

FIGURE 18. A vent condenser captures valuable treated water and some heat that would otherwise be vented out

The equipment to recover the treated water and much of the energy is a vent condenser (Figure 18). These condensers use a cool water stream, such as boiler makeup or process water (if available), to pull energy from the flash steam while condensing it to a recoverable high-temperature liquid. The result can reduce boiler load, capture valuable treated condensate, and also preheat a water stream where useful to elevate its temperature.

Many problems with condensate systems are caused by not handling the flash steam properly through a separate flash vessel, and the vent steam from that vessel contains value that should be recovered where economically feasible. Ref. 4 provides additional information regarding electric and non-electric condensate-pumping systems. ■

Edited by Mary Page Bailey

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Acknowledgement

Special thanks to Norm White, Jon Walter and Andrew Mohr for their kind review and comments.

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A Primer on pH Measurement

Understanding the basic principles of operation and construction designs of glass membrane sensors can help in choosing the right pH sensor

Colin Ziegler,
Endress+Hauser Liquid Analysis

IN BRIEF

One of the most critical measurements in liquid chemical processing is pH. In this article, the importance of the sensor construction to ensure quality measurements is discussed, as well as the critical factors to consider when choosing a pH sensor. This article also explores the key differences between analog and digital sensors. Finally, readers will learn how digital sensors can improve workers' safety while decreasing the maintenance efforts and lowering the possibility of measurement value drift.

FIGURE 1. The measurement of pH is important for many sectors of the chemical process industries, including pharmaceuticals, food-and-beverages and water/wastewater treatment

Background

The glass electrode pH meter, as we know it today, was first invented by Arnold Beckman in 1934 [*1*]. As with many scientific breakthroughs, the impetus for the development of a new technology came from a specific market need. In this case, it was the citrus industry of California that called for an accurate measure of acidity that would not be influenced by the presence of sulfur dioxide preservatives. Beckman's invention was based on the principle that measuring the activity of H^+ ions in a solution informs us about its concentration.

Beckman's glass-tube electrode method of measuring pH is still used today. However, several developments have helped to improve the reliability and longevity of modern devices. pH measurement is not only critical in the citrus industry, other industries like pharmaceuticals, food and beverages, and water treatment all rely on accurate pH measurement (Figure 1). Understanding the functional principles of pH measurement and developments in the technology is key to choosing the most suitable pH sensor for each application.

Basic principles of pH measurement

In pure water, a small number of molecules dissociate into H^+ and OH^- ions:

$$H_2O \leftrightarrows H^+ + OH^-$$

The extent of this dissociation can be described by the self-ionization constant of water, K_w, which depends only on the temperature.

$$K_w = [a(H^+)][a(OH^-)] \quad (1)$$

At 25°C, K_w = 1.01 $\times 10^{-14}$ for pure water. When acids or bases are added to the water, the number of ions change, but K_w remains the same, which allows us to use a consistent pH scale for all aqueous solutions. An acid has a higher activity of H^+ ions than OH^- ions, while a neutral solution has an equal activity of both. An alkaline solution has a lower activity of H^+ ions than OH^- ions. The relationship of pH and H^+ activity, $a(H^+)$, is defined by a logarithmic equation:

$$pH = -\log[a(H^+)] \quad (2)$$

In pure water, there is an equilibrium between H^+ and OH^-, so at 25°C, the activity of H^+ is nearly 10^{-7}. From Equation (2), the pH of pure water is $-\log_{10}(10^{-7}) = 7$, which is defined as neutral. For concentrations of H^+ greater than 10^{-7}, the pH will be less than 7 (acidic) and for concentrations less than 10^{-7}, the pH will be greater than 7 (alkaline).

A pH sensor is effectively an electrochemical cell that changes its electrical potential on a glass membrane based on the activity of

H^+ ions. The pH is directly proportional to the measured voltage. Because all other voltages in the cell are designed to remain constant, it is only the voltage generated across the glass membrane that represents the solution pH. The physical fundament of this voltage generation on the glass membrane is described by the Nernst equation:

$$U = U_0 + \frac{RT}{nF}\ln[a(H^+)] \quad (3)$$

Where:
U = sensor voltage, mV
U_0 = voltage at pH 7.0, mV
R = gas constant
T = temperature, K
n = load of ion (H^+ = 1)
F = Faraday constant

Converting from natural logarithms to base ten gives Equation (4)

$$U = U_0 + 2{,}3026\frac{RT}{nF}\log[a(H^+)] \quad (4)$$

Equation (4) is nearly a linear relationship between the measured voltage and pH, with a slope of approximately 59.16 mV/pH at 25°C.

The basic construction of a pH sensor includes certain components, as shown in Figure 2. It has two half cells joined in an electrochemical circuit.

The reference half cell. The reference half-cell (Figure 2) has a silver chloride element attached to a silver wire, which is inserted into a glass tube often containing 3 mol/L potassium chloride solution and a carrier gel matrix. The gel stabilizes the potassium chloride and helps keep the diffusion and substance exchange via the junction low. For a stable and reliable measurement, the concentration of potassium chloride should remain stable as long as possible. A junction separates the reference solution from the test solution and plays a vital role in cell performance. The junction forms a galvanic connection and thus allows the flow of ions to enable the electrochemical circuit to function. However, it must not allow the reference solution to be contaminated by the test material, nor allow the potassium chloride electrolyte to diffuse out of the sensor.

The measuring half cell. The measuring half-cell also contains a silver wire and silver chloride element. But this half-cell is galvanically separated from the test solution and has a glass membrane bulb, which is sensitive to changes in pH. The internal buffer solution is potassium chloride, and the outside of the glass membrane is exposed to the test material. The difference in activity of H^+ ions inside and outside the membrane creates a differential voltage, which is proportional to the pH of the test solution.

Ion exchange. A close-up view of the glass membrane (Figure 3) shows a gel layer on the inside and outside surface. This gel layer has a sophisticated structure that allows H^+ ions to migrate and form a potential. Each pH sensor brand has its own unique

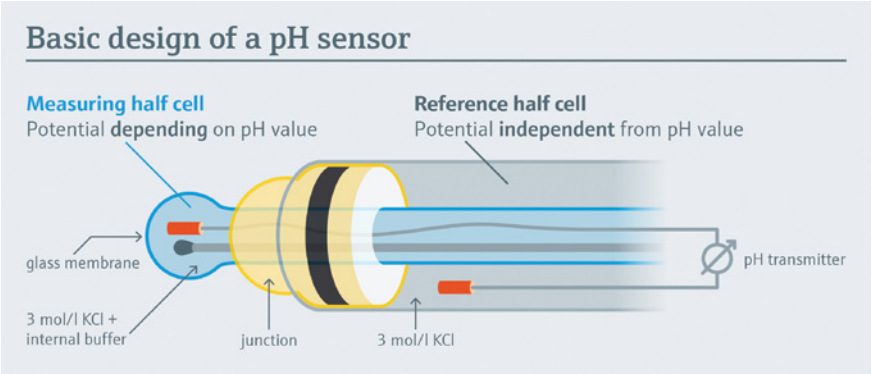

FIGURE 2. A basic pH sensor design is shown here

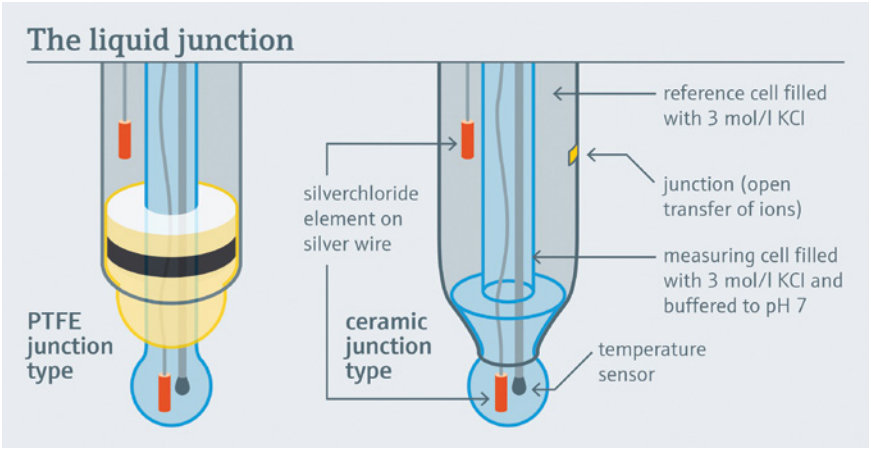

FIGURE 4. The liquid junction must allow the flow of ions between the reference electrolyte and the test solution. The junction must also minimize substance exchange between the reference and test solutions. Two junction designs are shown here

gel formulation using specially developed glass mixtures.

Temperature compensation. A crucial factor for pH measurement is temperature compensation. Modern sensors come with an embedded temperature probe to measure the actual temperature of the test solution. This is crucial because an increase in temperature causes the H^+ and OH^- ions to become excited and increase their activity. Measuring the same acidic test solution will give a lower reading (more acidic) at a higher temperature than at a lower temperature, because the sensor detects an increase in H^+ ion activity but not the corresponding increase in OH^- ion activity. Temperature compensation allows the effects of temperature to be removed at the sensor so that the reading remains accurate regardless of temperature variations.

The electrochemical cell. Each element in the electrochemical circuit contributes to the voltage across the probe. However, only the voltage across the glass membrane represents the pH of the test solution. For this reason, all other voltages in the circuit should be minimized and kept as constant as possible.

The flow of ions through the sensor as it measures pH can have negative consequences over time. If too many ions flow out of the electrolyte solution, then the concentration of the reference cell will drift from its target value and impact the integrity of the results. On the other hand, if too many ions of the test solution flow into the electrolyte solution, this will become contaminated, resulting in erroneous readings.

Factors affecting measurement

While the general design and construction of a pH sensor must meet the overall functional requirements outlined above, there are certain factors that can significantly impact the integrity of results and the life span of a sensor. This is particularly important in plant environments where conditions are more hostile. A real-time online pH sensor is exposed to temperature fluctuations as well as contaminants, both of which contribute to measurement drift and shortening of its expected life. These probes should be calibrated regularly (up to daily) to ensure there is no drift on the readings. However, laboratory pH probes operate in far more stable environments and therefore experience less drift and have a longer life.

The three critical elements that could affect probe accuracy and reliability are the following:

- The liquid junction
- The glass membrane
- The ion trap

The liquid junction. The liquid junction (Figure 4) lies between the reference electrode and the test solution. It normally takes the form of a ceramic plug, but it could also be made from polytetrafluoroethylene (PTFE) or left as an open aperture. The purpose of this junction is twofold. It must allow the flow of ions between the reference electrolyte and the test solution. Without this flow of ions, there is no electrical circuit and there can be no accurate measure of pH. On the other hand, the junction must slow down diffusion to minimize the substance exchange between the reference electrolyte and the test solution. This prevents the reference electrolyte from "bleeding out," thus changing the voltage of the reference electrode.

One way to maximize the junction performance is to use the high-quality ceramic material. The best ceramics have internal pores, which are consistent in size and distribution. Low-quality ceramics have too much variability in their internal structure. This variability means that each sensor behaves differently, making it challenging to develop consistent sensor performance. It is also possible for the ceramic pores to get plugged. If the blockage is severe, it may eventually prevent the flow of ions completely. This can happen if the pores in the ceramic are too big, allowing suspended particles from the test solution to wedge inside the pores.

Solid particles can also result from chemical reactions between the electrolyte and the test solu-

tion. Potassium, chloride and silver ions are all present at the junction from the electrolyte solution. Any of these components could potentially react with chemicals in the test solution, forming insoluble compounds. These may precipitate in the junction, blocking its pores.

The effect of solids formed by chemical reactions can be mitigated by using an ion trap.

The ion trap. An ion trap serves two primary purposes. Firstly, it prevents the silver ions from leaving the reference electrolyte; secondly, it prevents the pollutant ions from the test solution from contaminating the reference electrolyte. In this way, the ion trap inhibits the formation of precipitates at the junction and keeps the ceramic pores open for ion exchange.

The ion trap consists of small beads embedded in the gel and electrolyte behind the junction in the reference half-cell. The ion trap beads have exchange ions attached to them. An ion-exchange mechanism traps ions and prevents them from moving between the reference electrolyte and the junction using the beads.

As silver ions enter the top of the ion trap from the reference electrolyte, they come into contact with the beads. The silver ions replace the exchange ions at the top of the ion trap and the equivalent exchange ions are released from the beads at the bottom of the trap. The exchange ions do not precipitate and will not cause blockages in the ceramic junction.

At the same time, pollutant ions are entering the ion trap from below. They also come into contact with the beads and exchange places with the exchange ions. The pollutants are, therefore, prevented from reaching the reference wire and interfering with the measurement.

Without an ion trap, the formation of precipitate in the ceramic junction would severely limit the life of the pH sensor. The ion trap is, therefore, a fundamental element for preserving the integrity of results for a longer time, thus extending the life span of the pH probe. This is particularly important in heavy or polluted chemical applications.

The glass membrane. pH sensors are designed and constructed with the aim of keeping all the voltages in the electrochemical circuit small and unchanging. The only exception for this is the voltage across the glass membrane. This changing voltage represents the pH of the test solution. To achieve this, the membrane must be as sensitive as possible to minor changes in ion activity on either side of the glass.

The glass membrane is 0.2 to 0.5 mm thick. The gel layer on each side of the glass is thinner, at approximately 100-nm thickness. An essential element in the construction of the membrane is the doping of high concentrations of alkali metal oxides. These metal oxide ions allow the ion exchange from the solution into the gel layer, giving rise to the voltage

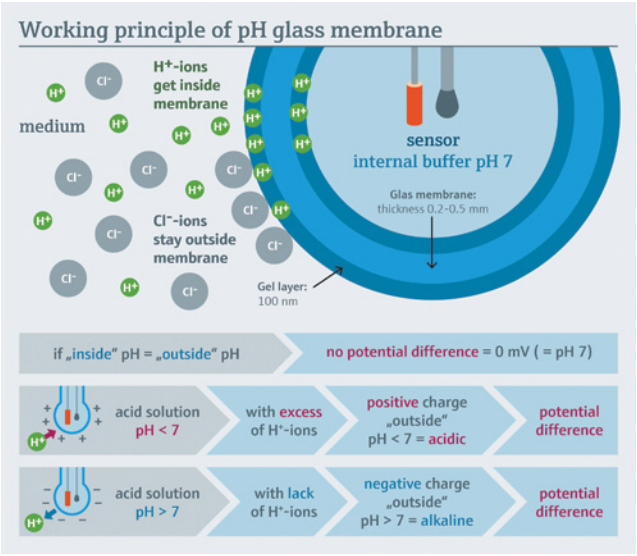

FIGURE 3. Ion exchange takes place at the glass membrane of a pH sensor

change across the membrane.

Because ion activity changes with temperature, the characteristics of the glass must be suitable for the measuring conditions. Composition of the glass membrane is a highly confidential field of research for pH sensor manufacturers. Different glass membranes should be used for different temperature applications. Glass membranes are also designed for some specific chemical interactions, such as sterilization applications or test solutions containing hydrofluoric acid.

Digital versus analog sensors

Analog systems. Analog pH measurement installations consist of a sensor, a transmitter and a cable connecting the two together. The entire system works together to measure the pH, which is transmitted to a control system using a 4–20-mA signal or digital communication protocols. This means that the sensor is not a stand-alone device, but is dependent on the wiring and the transmitter to form a measurement loop. A significant disadvantage of this approach is that a change to a single component affects the pH measurement. For example, if the wire between the probe and transmitter is changed, the readings will change, and the entire system must be recalibrated.

Digital systems. Digital pH measurement systems contain all the components for measurement on the sensor itself. The cable from the sensor to the transmitter supplies power and transmits information digitally. Therefore, it does not affect the measurement. Changing the cables from the sensor to the transmitter will not affect the pH measurement, which eliminates the need for recalibration. When replacing a digital probe in the field, it can also be immediately commissioned, as long as it has been calibrated in a laboratory setting. Digital sensors are insensitive to moisture in the connections like analog sensors are, because these connections are not part of the measurement loop.

The hazards of field work. The chemical industry is often a hazardous environment, which uses products and materials that can cause serious injuries to operators or maintenance technicians. It is vital to keep personnel out of the field as much as possible to minimize the risk of accidents. Digital pH probes help achieve this because they can be replaced without field calibration. In contrast, analog systems must be recalibrated in the field after any component is changed, which prolongs the time a person must spend in the field working on the equipment. This leads to a higher safety risk and to increased maintenance costs due to the time that it takes to complete the task.

The benefits of information storage. Digital sensors also have the benefit of internal data storage, which captures critical information about the process and the condition of the sensor.

Calibration data can be stored in the head of a digital sensor. This enables the device to be calibrated in the laboratory before field installation. The device will read accurately without the need for field calibration checks. Digital devices store their original reference calibration along with the records of previous calibrations. This allows maintenance technicians to optimize the calibration frequency by monitoring the drift in the readings over time.

Digital sensors also store critical operating information. For example, they record extreme temperature or pH events that could reduce the life span of the sensor or its current accuracy. This information is vital for predictive maintenance and for as-

sessing the health of a sensor. Advanced applications can use this information to develop models and create alerts when a calibration or maintenance intervention is required.

For those instruments used in sterile applications, the digital head can store the history of clean-in-place (CIP) and sterilize-in-place (SIP) cycles. The frequency of these cycles affects calibration optimization, as well as expected life.

All these benefits are only available from digital pH sensors, which store information in the digital head so that it can be accessed by software applications or maintenance technicians for improved maintenance and better accuracy.

Future trends in pH sensors

There have been significant advances in the design and construction of pH sensors since the original glass electrode pH sensor was invented by Beckman. New junction designs using high-quality ceramic or Teflon materials offer much better and durable performance than former designs and materials. Glass membranes have also improved. They are optimized for different applications, with each one having its own advantages and disadvantages. The ion trap is the high point of design innovations for pH sensors and has played a major role in increasing their life span.

Current developments focus on the digitalization and the use of information to improve predictive maintenance and reduce the safety risk for personnel. For example, equipment-health monitoring applications are becoming more sophisticated and more accurate at predicting problems before they affect the quality of results.

In the near future, pH sensors are likely to store even more information about their use and their operating conditions. Availability of this information in cloud-based applications will enable higher-level monitoring and analysis to improve their performance. These systems will enable users to optimize their maintenance intervals, reduce their costs and extend the life span of their sensor. ■

Edited by Gerald Ondrey

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IFAT Munich

Emile Egger & Cie

Endress+Hauser

Lödige Process Technology

IFAT 2022, the world's leading trade fair for water, sewage, waste and raw materials management takes place from May 30 to June 3 at the Munich fairgrounds (www.ifat.de). More than 3,300 exhibitors from 58 countries will be displaying their equipment in 18 exhibition halls covering 260,000 m^2 of exhibition space. In addition to the exhibition, there are a number of special supporting programs, including: The Future of Water — Access and Quality; Circular Economy and Resource Efficiency; Sustainable Cities and Municipalities; Intelligent Drives and Zero Emissions; and Mineral Waste Cycle and Sustainable Road Construction. There is also a special area for start-ups, which spotlights innovators, future collaborations, profitable-production processes and specific technology solutions.

The following is a sample of some of the products being exhibited at IFAT 2022.

A new generation of control valve

The IBS-series (photo) is a redesigned and technically revised version of this company's Iris process-control valve. The new series features a compact structure with shorter installation lengths. The visual position indicator has been completely revised and is clearly visible from three sides, even from a long distance; this is in addition to the electronic feedback of the variable-speed drive position to the SCADA system. The valve's gas-tight design without spindle feedthrough opens up many new possible applications for regulating chemicals and industrial gases. Leak-monitoring and flushing systems can be connected without changing the design. Its robust design and self-cleaning segments also make the valve a reliable regulator for raw sewage or sludge. Hall B1, Stand 345 — *Emile Egger & Cie SA, Cressier NE, Switzerland*
www.eggerpumps.com

A cloud-based software service for monitoring waterworks

Netilion Water Networks Insights (NWNI; photo) provides reliable monitoring of flow, pressure, temperature, level, water quality and other measurements. This software service connects all levels of water supply systems, empowering service providers and water associations to manage multiple control and data sources through a single interface. These sources include field devices, industrial controllers, data-transfer components, data recording and archiving devices, analysis and forecasting tools, and others. NWNI provides access to all measurement data gathered in a water network and transmitted to the cloud, whether its users are accessing the system from a control-room computer, via a laptop at home, on a tablet in the field, or from a smartphone on the move. The web-based interface provides users with complete system monitoring, and when limit values are exceeded, or in the event of failure, it delivers alarms to users via e-mail, SMS or push notifications. Hall C1, Stand 451/550 — *Endress+Hauser, Reinach, Switzerland*
www.endress.com

Mixers for efficient treatment of sewage sludge

Continuous Ploughshare mixers (photo) enable operators of municipal and industrial sewage works to tailor their treatment of wet and dry sludge entirely to its intended use. Wet and dried sludge that has been mixed and treated inside a Ploughshare Mixer in a continuous process boasts a pumpable consistency, exactly the right moisture content required to achieve the necessary calorific value and a particle size that ensures the proper consistency. This provides reliable protection against the sludge sticking or turning into a paste. Additives such as lime can also be added easily during processing. Ploughshare Mixers operate on the fluidized-bed principle. Specially developed shovels rotate close to the wall inside a horizontal drum, creating a fluidized bed. The process enables a high degree of homogeneity and constant reproducibility. Retention times, duration of treatment and other process variables can be modified depending on the characteristics being sought. Hall A2, Stand 520 — *Lödige Process Technology, Paderborn, Germany*
www.loedige.de

This new high-pressure pump is powerful and lightweight

The new high-pressure plunger pump model P3-19 (photo) has higher power density than its predecessor, the KD708, and opens up a wider field of application with 10% more power. The P3-19 includes a crankcase sealing as standard to ensure even higher reliability compared to the predecessor. Thanks to nearly identical mounting points to those of the KD708, lighter weight and a more compact design overall, switching to a P3-19 is easy for users that are looking for an upgrade. The new P3-19 features a compact design and an optimized position of the input shaft, which allow for easy installation on any sewer cleaning truck. The pump delivers flowrates up to 324 L/min with operating pressures from 140 to 250 bars. The pump weighs just 175 kg and has a maximum drive power of 83 kW. Hall C4, Stand 451— *URACA GmbH & Co. KG, Bad Urach, Germany*
www.uraca.com

Innovation in sewage sludge drying

This company offers sludge drying systems (photo) for the treatment of sludge from municipal and industrial wastewater-treatment plants. The company made use of its long-term experience in thin-film evaporation and applied it to sewage sludge drying. The result is reduced energy consumption for sewage sludge drying. The company can now provide the use of a low-temperature heating source (down to 90°C); process scheme 1, which provides 10% saving in heating energy; and process scheme 2, which provides up to 45% savings in heating energy. The new options can be achieved with existing, well-known equipment and are already proven at pilot scale. Hall A2, Stand 120 — *Buss-SMS-Canzler GmbH, Butzbach, Germany*
www.sms-vt.com

Large volumes of air delivered by these blowers

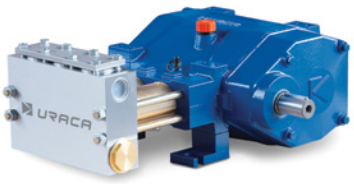
This company's PillAerator turbo blowers (photo) are suitable for aeration processes with large air requirements in wastewater treatment. The blowers are also used for industrial applications, such as flotation, fermentation and fluidization. The turbo blowers deliver volume flows from 50 to 275 m^3/min and differential pressures of 1.3 bars. The turbo impeller is driven by a high-speed motor whose shaft is mounted on magnetic bearings, enabling operation that is completely free of lubricants and wear. The smart magnetic bearing is protected against power failure and actively controls the rotor position to keep it in its orbit, even in the event of major operating-parameter fluctuations. The PillAerator is available for three optimized pressure ranges: 600 mbar, 800 mbar and 1,000 mbar. Hall A1, Stand 143/242 — *Kaeser Kompressoren SE, Coburg, Germany*
www.kaeser.com

Save energy with this well pump

One of the highlights of this company's exhibit is the new UPA S 200 8-in. well pump (photo). Featuring an optimized hydraulic design, pumps of this type achieve very high levels of efficiency. When combined with high-efficiency synchronous motors from the UMA-S type series and a variable speed system, energy costs can be reduced significantly, especially in systems with fluctuating flowrates. All cast components are high-grade stainless-steel investment castings made of 1.4408 or, optionally, 1.4517 steel. The company is also be showcasing the new Delta Macro SVP as an example of pressure-booster systems for supplying water in building-services applications. The new, ready-to-connect pressure-booster systems are designed for high flowrates. Equipped with two or up to a maximum of six Movitec high-efficiency centrifugal pumps, these fully automatic systems are supplied ready-to-connect. The microprocessor control unit starts and stops the pumps according to demand using a frequency inverter for speed control. Hall B1, Stand 227/326 — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

This radar sensor handles any level-measurement task

Vegapuls 6X (photo) is a new radar sensor that is said to be able to measure in every conceivable level application. The new device has a self-



URACA

Buss-SMS-Canzler

Kaeser Kompressoren

KSB


VEGA Grieshaber

diagnosis system that immediately detects damage or interference that ensures significantly higher availability and safety. It has new radar-chip technology, with expanded application possibilities and simpler operation. In addition to SIL certification, the matter of cybersecurity has also been fully accounted for: compliance with security standard IEC 62443-4-2, which specifies the strictest requirements for secure communication and access control. Hall C1, Stand 239 — *VEGA Grieshaber KG, Schiltach, Germany*
www.vega.com

This decanter centrifuge efficiently dewaters sludge

Flottweg

This company is presenting its most innovative solutions in the field of sludge dewatering and thickening, as well as industrial wastewater processing and oil sludge recycling. Specially designed for high-level dewatering of sewage sludge, the Xelletor series (photo) delivers the most economical solution for sewage sludge dewatering and has heralded a new generation of decanter centrifuges since its launch in 2018. The system delivers an increase in dry matter content in the dewatered sludge of up to 2%, and reduces sludge volume by up to 10%, compared to the C-series centrifuges. Also, up to 20% less flocculant is required, and energy consumption reduced by up to 20%, the company says. It also boasts a separation efficiency of over 99% and delivers 15% more throughput, compared to the C-series centrifuges. Hall A1, Stand 550 — *Flottweg SE, Vilsbiburg, Germany*
www.flottweg.com

Accurately measure turbidity with this portable device

The TB350 (photo) is said to be the most advanced portable turbidimeter on the market. It uses Multipath 90° BLAC (backscattered light absorbing cavity), a new, patented sensor technology. Two detectors are arranged at 90-deg, which ensures a purely nephelometric measuring principle. During the turbidity measurement, two different path lengths of the incident light beam through the sample are cleverly exploited. With the novel BLAC technology, the light-absorbing trap almost completely eliminates unwanted stray light and provides extremely accurate results for low turbidities down to 0.01 NTU. The TB350 has the accuracy


Tintometer

of a laboratory measurement, but in a portable instrument. Highest accuracy is guaranteed in the lowest turbidity range from 0.01 NTU, while maintaining the precision level in the highest turbidity range up to 4,000 NTU. The TB350 is available as an infrared or white light version, is compliant with valid ISO 7027 and U.S. EPA (pending) regulations and standards. Hall C1, Stand 329 — *Tintometer GmbH, Dortmund, Germany*
www.lovibond.com

Recovering phosphorous from sewage sludge — on site

The most promising phosphorus-recycling methods, in terms of sustainability, conservation of resources, effectivity and long-term cost-efficiency, are those processes in which phosphorus is recovered from sewage sludge directly on site. One such process has been developed by this company in cooperation with the CUTEC research center at the Clausthal University of Technology. It can be adapted to different recycling capacities and will be ready for commercial use in 2023. The recycling system can be added to a wastewater treatment plant, eliminating the need for transportation of the sewage sludge. The sludge is dried on-site and the phosphorus recovered — without incineration and ash storage and without using chemicals. The sewage sludge is fully utilized, generating marketable products. Recycled phosphoric acid, for instance, has a wide range of applications in a variety of industries. The process requires very little space and can be scaled to suit different recycling capacities, making it suitable for municipalities of all sizes. Hall B2, Stand 127/226 — *Grenzebach BSH GmbH, Bad Hersfeld, Germany*
www.grenzebach.com

Using ozone to combat micropollutants

Ozone breaks down trace substances through oxidation or converts them into smaller molecules, which are easier for micro-organisms to break down in a post-treatment stage or can be removed by means of absorption. This combination of processes delivers an improved overall cleaning result and generally removes more than 80% of trace elements from wastewater. At the same time, operating costs are lower than those of comparable technologies. This company's new O_3 system, Dulczon OZLa, can be fitted with up to 16 O_3-generator modules. The modules can be activated and deactivated as required. The amount of O_3 produced can therefore be adapted to fluctuations, for example in a clarification plant where varying volumes of waste water are treated. Hall A3, Stand 451/550 — *ProMinent GmbH, Heidelberg, Germany*
www.prominent.de

Gerald Ondrey

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6TH ANNUAL CONNECTEDPLANT CONFERENCE
Harnessing Digital Tools to Drive Success

The 2022 Connected Plant Conference (CPC; www.connectedplantconference.com) will take place May 23–26 in Atlanta, Ga. The event offers a comprehensive technical program, with expert speakers providing insights on the practical aspects of digitalization, as well as updates on state-of-the-art technologies. The event will also include a Digital Arena, where technology providers will showcase their digitalization solutions. The following is a small selection of the highlights that will be showcased at CPC's Digital Arena.

Factory optimization software for chemicals manufacturers

This company's software can help businesses to continuously optimize production in ever-changing conditions. With fast, clear insights powered by white-box machine learning, users can increase sustainability and profits across their entire enterprise, without sacrificing quality. One unique highlight of this platform is the ability to virtually replicate multi-stage batch processes within the software. With this functionality, users can model complex interactions between stages of batch processes with a high degree of accuracy, providing key data for decision-making. Booth 13 — *Fero Labs, New York, N.Y.*
www.ferolabs.com

Merge APM with work execution management and risk analysis

This company's Enterprise Suite delivers next-level integration of asset-performance management (APM) tools with risk- and priority-driven work management. The two flagship modules within the suite are Criticality Analyzer, which facilitates rapid and accurate cross-functional, multi-variable risk analyses of an entire operation; and InField Mobile, a mobile work-management platform available for both iOS and Android devices. The cloud-based, true multi-tenant suite is designed to help users manage assets in the context of an overall asset-management program. It includes: integrated mobile work management; detailed master-asset libraries for failure modes and asset-condition management; criticality and risk analysis; and risk-based decision-making tools — all connected by a central intelligence-guidance system that directs businesses to appropriate asset strategies. The suite delivers effective management of both vertical (plant) and horizontal (network) assets within a single platform and supports an ISO 55000 asset-management framework. Booth 16 — *MentorAPM, Phoenix, Ariz.*
www.mentorapm.com

New process simulator includes embedded sustainability metrics

This company has launched its next-generation Process Simulation cloud-enabled software, which can optimize existing processes and improve sustainability through its modern architecture and open modeling environment. Process Simulation is a lifecycle simulation platform that can help users design new plants more sustainably and optimize existing plants by using embedded sustainability metrics. The new simulation platform provides an open modeling approach to shorten the development time of new process equipment models for wind and solar power generation, water electrolysis and biodiesel production. It has one simulation model for steady-state and dynamic process design that allows users to quickly understand the impact of variable wind and solar resources on the process. Methods for calculating greenhouse gas emissions and sustainability metrics, such as energy intensity, carbon efficiency, water intensity and more, are also included, as well as integrated tools for multi-objective optimization of operating cost and process sustainability. Booth 311 — *Aveva plc, Cambridge, U.K.*
www.aveva.com

New venture aims to close the gap to zero unplanned downtime

Novity is a new venture to commercialize predictive maintenance technology that reduces unplanned downtime in industrial manufacturing operations using equipment sensors and proprietary algorithms to visualize the future health of production assets. The Novity TruPrognostics engine relies on a combination of machine learning and physics-based models of equipment. This allows Novity to predict equipment failures with 90% or better accuracy and lead times of months, not weeks or days. In addition to increasing the accuracy and prediction horizons of the solution, Novity's TruPrognostics engine also reduces the need for large amounts of data to deliver results. By leveraging a library of pre-built physics-based models, predictive maintenance is accessible to users who lack the historical data required by other solutions. Booth 110 — *PARC, a Xerox company, Palo Alto, Calif.*
www.novity.us

MTP integration leads to more flexible production

This company's zenon software platform incorporates the Module Type Package (MTP), a manufacturer-independent standard created by NAMUR (www.namur.net). MTP is a convention allowing a manufacturer-neutral description of modular production-plant equipment that includes a unified representation of the information regarding the individual modules, such as which data objects are acquired, or which services are meant to be rendered and the related interfaces. This aims to integrate different modules with a common process-control system to ease the creation of manufacturer-independent automation for modular production plants. The zenon Engineering Studio platform features an import interface for MTP file integration so that automation designers can seamlessly integrate them into overall zenon projects and use them exactly like native objects. Booth 2 — *COPA-DATA USA Corp., Princeton Junction, N.J.*
www.copadata.com ■

Mary Page Bailey

Detecting and Preventing Spills and Leaks

Comprehensive planning, along with appropriate level-measurement technologies and safety instrumented systems, can empower plant personnel to significantly reduce the likelihood and severity of hazardous chemical spills

Howard Siew and Brian Howsare
Endress+Hauser

In most industries that manufacture, use or store chemicals and other hazardous liquids, a spill prevention, control and countermeasure (SPCC) plan is required to operate storage tanks. Even when not mandated, an SPCC plan can help prevent damage to facilities, contamination of the environment and injury to personnel.

An SPCC plan is designed to prevent spills from occurring — and control them when they do — by deploying countermeasures to mitigate the damage and extent of a spill. This usually begins with installing or upgrading level instrumentation throughout a facility.

Chemical spills are most frequently caused by tank overfill or process leaks. While preparatory prevention is the goal, the possibility for incidents is never zero. This article covers prevention and detection measures for overfill and leak events, as well as instrumentation-specific requirements to accomplish these tasks.

Overfill prevention specification

Overfill prevention of chemical storage tanks is best implemented by combining radar — or another continuous level-monitoring technology — with point-level switches. With such a setup, the continuous level-monitoring instrument provides a process parameter for use by the primary control system, while at least one point-level switch is dedicated to an isolated safety instrumented system (SIS).

Industry best practice for managing tanks combines existing prescriptive standards from the American Petroleum Institute (API; Washington, D.C.; www.api.org), such as API 2350, with functional safety standards from the International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch), such as IEC 61511. The API 2350 specification can be met by using a SIS designed in accordance with IEC 61511. API 2350 prescribes methods for preventing both automated and manual tank overfills, and achieving its requirements dictates implementing a risk assessment system. Both IEC 61511 and API 2350 require proof-testing of device-safety functions at regular intervals to demonstrate SIS functionality in relation to safety requirements. This includes checking all relevant safety devices, such as level switches, signal horns and flashing beacons.

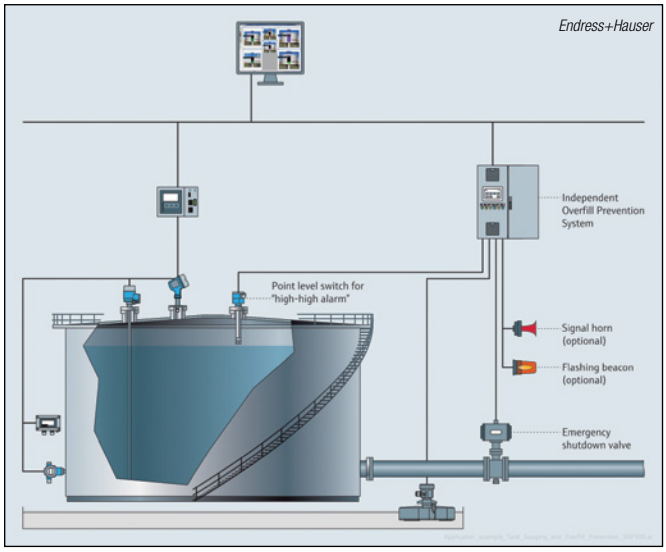

FIGURE 1. A typical overfill-prevention system requires high-high level detection in a safety instrumented system (SIS) isolated from the primary tank-gauging control system

When implementing a SIS, users have the option to use pre-engineered systems or create customized configurations, depending on their specific site needs. While not a fit for every application, a pre-engineered SIS significantly eases testing efforts and reduces costs by providing users with the ability to execute systemwide proof tests with the press of a button during commissioning and operation, and throughout equipment lifecycles. This can reduce the time it takes to proof-test a tank farm's SIS to minutes, rather than hours or days.

To meet standards and ensure safe functionality, a SIS must be independent of all other facility control systems. Every equipment element — including level and temperature control and alarming devices — must be dedicated exclusively to the SIS.

High-level overfill prevention switches, like vibrating tuning forks, provide indication when the material in a tank reaches a dangerously high point. This instrument is often referred to as a high-high level switch because it is mounted above the high-level switch used to indicate the normal fill stop point. If a high-level switch or the filling control system fails, the high-high level switch prompts an alarm system to notify personnel of overfill (Figure 1).

Because high-high level switches are mounted above normal maximum fill points, years can pass without activation. For this reason, testing these switches regularly is critical to verify functionality so they work correctly when dangerous overfilling situations arise. These regular tests should be part of any SPCC plan.

Reduce risk

While testing high-high level switches regularly is required to maintain overfill SIS protection, elevating a process to an unsafe level

FIGURE 2. This level switch supports automated in-situ self-testing for critical safety applications

to test these switches is not permitted under API 2350 for aboveground storage tanks.

Most facilities resort to removing switches from tanks for testing. In these cases, operators typically perform bucket tests, immersing a switch in its process liquid to ensure it works properly. Removing a switch for testing incurs the risks of downtime, lost production and potential chemical exposure for personnel. Additionally, personnel must be available to remove the switch, perform the test and reinstall the switch.

This method has additional drawbacks because removing and reinstalling switches subjects them to potential damage. They may not work correctly when reinstalled, negating a test. For these reasons, it is better to use point-level switches that support in-situ testing for critical safety-related applications (Figure 2).

Some plants rely on continuous level technologies, such as free-space radar, guided-wave radar and ultrasonic transmitters to provide overfill prevention with the assumption that continuous level measurement will provide an alert when conditions go awry. However, this thinking fails to consider process occurrences, such as foam, condensation, product buildup and other issues, which can create false readings.

For this reason, point measurement is better suited for detecting high-high levels to prevent accidental overfill and associated spills, rather than continuous level-monitoring instrumentation.

Many switch technologies for high-high overfill-prevention applications exist, including vibrating tuning forks, capacitance, ultrasonic gap

FIGURE 3. Since very small changes in level can translate to large fluid losses, radar level transmitters should be able to detect tank levels within an accuracy span of less than 1 mm

switches, float switches and more. Engineers must carefully consider the best instrumentation options for each application, selecting equipment fit to tank geometries, liquids in use and industry accuracy and testing requirements.

Even the best overfill-prevention plan can go wrong, resulting in a spill. Furthermore, not only tanks can experience leaks, but also pumps, pipes, valves and fittings. When any of these adverse events occurs, rapid detection can greatly mitigate the chemical volume released and associated damage.

APPLICATION EXAMPLE

Installed in a drainage sump pit near a tank or pump yard, an oil-leak detector float sensor provides leak detection of petrochemicals, vegetable oils and more. Such a sensor combines vibronic and conductive technologies with dual-level logic to distinguish the presence of specific fluids for effective leak monitoring.

The conductive probe detects water-based liquids, while the vibronic tuning fork confirms the presence of oil or air. Equipped with process diagnostics, these instruments transmit status data if a cable fails or liquid freezes, assuring failsafe operation.

Combined vibronic and conductive level-sensing technologies can identify the presence and types of liquids in sumps and dikes

Advanced monitoring software works together with advanced instrumentation by executing algorithms that generate notifications when detecting anomalies or certain conditions. For example, software can notify operators of a high rate-of-change in a tank level, signaling a process issue that requires attention. ❑

Leak detection and prevention

Chemical leaks can wreak catastrophic consequences extremely quickly, and the best method to mitigate damage is to prevent their occurrence or, at the very least, expediently detect them. Doing so requires proactive measurement. Level instrumentation can safely and reliably monitor the contents of a tank, annunciating an alarm in the event of an overfill event or leak.

As the first line of defense in tank leak detection, a continuous level instrument must always identify tank-level fluctuations. If a tank level ever decreases when its associated control system is not actively lowering it, this signals the presence of a leak, and the monitoring system must notify plant staff. Demonstrating the criticality of detail in level measurement, an unexpected drop in level of just 1/8 in. in a 30-ft diameter storage tank — a common size at petrochemical facilities — represents over 60 gal of fluid leaked. As a result, accuracy must be measured in fractions of millimeters. Many radar level gages can provide accuracy of 0.5 mm (Figure 3).

For many hydrocarbons and chemicals, tank instrumentation must also incorporate temperature compensation, because chemical volume expands and contracts with temperature changes. These volumetric fluctuations cause levels to change, even when no fluid escapes or enters a tank. Temperature sensors with multiple measurement points and high-precision accuracy are required for such applications.

Monitoring level measurement with a software system is the best way to determine when level changes should and should not be occurring. When the level drops at a time it should be stable or rising, the system must alert facility personnel of a possible leak or spill.

Monitor the dike

The second line of leak-detection defense is equipping level switches inside retention dikes. All accumulation, including rainwater after a storm, must be removed to maintain dike availability for catching spills or leaks. Level switches to reliably indicate any liquid, such as tuning forks, are best suited for this application.

There are many specialty instruments that indicate the presence of liquid and its conductive properties. This helps identify the liquid to distinguish whether it is rainwater (conductive) or a hydrocarbon (nonconductive). By combining a vibrating tuning fork, which detects liquid regardless of its conductivity, and a conductivity switch, facility personnel and software systems can identify the type of accumulation in the dike.

When the dike is empty of all liquid, neither the tuning fork nor the conductivity switch report any liquid. When the dike is full of water, both the tuning fork and the conductivity switch report liquid presence, assuming the water is conductive, as is typically the case with rainwater. When the dike contains a nonconductive liquid, the tuning fork reports presence of a liquid, but the conductivity switch does not, indicating a spill or leak of a nonconductive chemical.

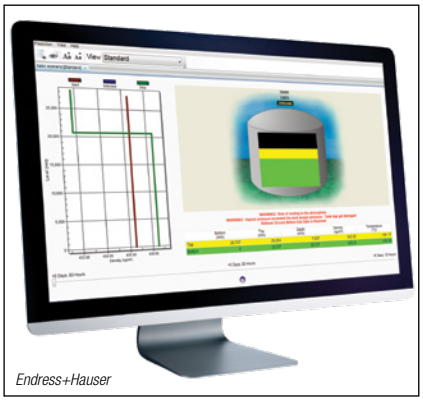

FIGURE 4. Computer-based tank monitoring tools can promptly alert operators of diagnostic and process issues to minimize plant disruption

Maintenance is key

Accurate instrumentation is the cornerstone for any safety system's reliability. One of the greatest challenges in maintaining instrumentation reliability is a lack of awareness when issues arise.

Many modern instruments, particularly smart instruments, transmit process and device diagnostics, in addition to primary process variables. By monitoring these diagnostic data at central processing points and implementing notifications, control systems can alert operators of automatically detected instrumentation issues, identified directly by the instruments (Figure 4).

Diagnostic information is useful for implementing predictive maintenance programs because instrumentation usually begins to register issues prior to complete failure. This can help maintenance staff focus their efforts where most needed, reducing unplanned downtime, along with unnecessary and costly instrument replacement.

Incident response

The more quickly a SIS can identify chemical spills and leaks, the better a facility can control incidents and respond appropriately. The right level instrumentation can provide early indication of issues, and then dispatch alerts to mitigate risk. When an incident occurs, a well defined response can make the difference between acceptable recovery and catastrophic harm to equipment, the environment or humans.

This requires creating a response plan and frequently training personnel. The plan involves assessing the risk each storage tank presents, incorporating its chemical contents, volume and the potential damage a spill or leak could cause. Planners should consider the many types of hazards and events that can occur, creating procedures to handle these permutations, so personnel know exactly what equipment and safety measures are at their disposal to mitigate incidents.

Available equipment includes spill clean-up products, floating dikes, absorption material, emergency pumps, safe storage tanks and more. In addition to facility personnel, most industries specify regional emergency groups and authorities who must be notified when spill events occur. A well-planned and well-practiced response plan limits the damage, reducing consequences.

Tank-inventory management software can help by detecting leaks and spills, directing emergency procedures (such as shutting off pumps), alerting personnel and documenting the spill.

Executing the SPCC plan

A sound SPCC plan greatly reduces the likelihood and severity of chemical spills and leaks. Proper instrument selection for overfill prevention provides the best solution to prevent spills, along with frequent testing to ensure equipment functions properly when needed. By implementing smart instruments and software monitoring, it becomes easier to monitor level changes and other process conditions, providing timely alerts of leaks and minor spills.

Retention dike monitoring helps signal the presence of an issue and identifies the type of liquid leaked. Prompt notification of a leak or spill enables rapid response, and comprehensive response plans and training reduce the severity of incident damage to a minimum. ■

Edited by Mary Page Bailey

Authors

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Brian Howsare is the International Inventory Management Solutions (IMS) business development manager for Endress+Hauser (same address as above). He has been in the process instrumentation industry since 1984 and has been with Endress+ Hauser since 2001. With Endress+Hauser, he has held several positions, including level and digital communication specialist, certified Profibus engineer and technical sales and solutions business manager. In his current role, he works closely with terminals, tank gauging systems, inventory control and the industrial internet of things, using wireless and cellular remote monitoring instruments and gateways.

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Inside:

A classic mixing tool for the petroleum industry

Ross LPD Static Mixers are rugged, reliable devices that combine excellent inline mixing with minimal pressure loss

Ross Low Pressure Drop (LPD) Static Mixers are used throughout the oil and gas industry for turbulent-flow mixing applications.

Shown are removable LPD mixing elements supplied with retainer ring and flanged housing.

These heavy-duty low-maintenance devices serve in continuous operations where high performance and accuracy are required, such as on-line water determination of crude oil; dosing of various additives into gasoline; blending different kinds of fuel oils; gas-gas blending; and pipeline reactions, among others.

Static mixers have no moving parts and the energy for mixing is available in the form of pressure. Pressure loss – a natural consequence of static mixing – sometimes becomes the deciding factor in mixer selection. The LPD Static Mixer remains a classic choice for many inline blending requirements due to its simple and durable design capable of uniform mixing with little pressure loss. The mixer elements consist of semi-elliptical plates carefully positioned in series to split and rotate the product 90 deg. in alternating clockwise and counterclockwise directions.

LPD mixers in diameters from 1 in. through 2.5 in. are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Units as large as 48 in. diameter can be supplied as stand-alone mixer elements or as modules complete with a mixer housing and injection ports.

Established in 1842, Ross is one of the oldest and largest mixing equipment companies in the world. Ross mixing, blending, drying and dispersion equipment is used throughout many industries in the manufacture of foods, adhesives, electronics, coatings, cosmetics, pharmaceuticals, plastics and composites.

www.staticmixers.com

Water Quality Analysis Tool Replaces up to 6 Lab Instruments

The Myron L Company's Ultrameter II 6PFC^E delivers benchtop lab-accurate measurements in one compact, easy-to-use, easy-to-calibrate handheld device.

The Ultrameter II 6PFC^E provides a comprehensive suite of in-situ water quality analysis tools that are designed to replace more costly and less convenient laboratory equipment. A true one-handed instrument, the 6PFC^E delivers Conductivity, Resistivity, TDS, pH, ORP, Free Chlorine Equivalent (FC^E), and Temperature measurements quickly and easily with the press of a button. Simply rinse and fill the sensor well and/or cell cup with solution, press a measurement key, and note the measurement value or store it in memory. With the optional bluDock accessory package, the 6PFC^E can transmit data wirelessly to the free **Myron L** Guardian^2 desktop application. This application saves data in .mlcx files in a secure, encrypted format. For users who wish to view and/or manipulate data in other applications, Guardian^2 can export data files in .csv, .xls, .xlsx and .pdf formats.

Unlike other similar meters, 6PFC^E Conductivity/TDS measurements feature the ability to select from one of three preprogrammed solution models, KCl, NaCl, or Myron L's own 442 Natural Water Standard. The result is benchtop accuracy of ±1% of reading in a handheld instrument. Temperature compensation for the three preprogrammed solution types is automatic to 25°C or can be disabled by the user as required. When working with a known solution, the user can program a temperature compensation ratio and a Conductivity to TDS conversion ratio in User mode. Autoranging capabilities provide increased reading resolution across a broad range of applications.

pH readings are also temperature compensated. The user can choose to perform a 1-, 2-, or 3-point calibration depending on the range of samples measured to achieve ±.01 pH accuracy. The pH sensor is of a proprietary construction and includes a large potassium chloride reference solution reservoir for long life. Myron L pH sensors are also user replaceable.

ORP measurements utilize a 99.9% pure platinum electrode and a reference junction that is shared with the pH sensor. Accuracy achieved is ±1 millivolt.

In addition, the 6PFC^E features a groundbreaking new way to determine Free Available Chlorine based on a predictive ORP value. Empirical measurements of the chemical activity of a solution are made without the hassle and subjectivity of colorimetric and test-strip methods.

Calibration is simple to perform using up and down arrow keys and a digital interface. And the 6PFC^E is IP67 dust-tight and waterproof, NEMA 6 submersible, and buoyant. Myron L service and technical support are included for the life of the product.

www.myronl.com

Getting the Most Value from a Process Simulator

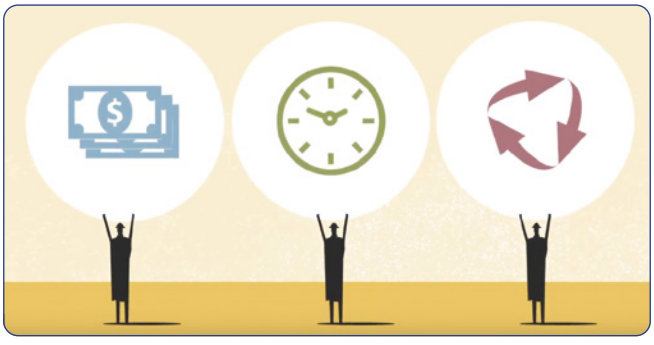
Using a process simulator to build detailed flowsheets account for only a fraction of the tasks that are required of chemical engineers. To get the most value from process simulation technology, consider exploring new ways to take advantage of all the features that can support the daily needs of chemical engineers. For example,

- **Plot several TPxy diagrams to validate thermodynamic behavior.** While the economic benefits of thermophysical modeling are not easy to quantify, there is a clear advantage to anticipating the phase behavior through a range of process conditions.

- **Run sensitivity analyses to test system vulnerabilities or to design a piece of equipment.** For example, sensitivity analysis tools can be used to explore operating parameters like how a change in feed composition can affect the product streams. It can also be used for design situations like finding the optimal feed tray location in a distillation column.

- **Build a digital twin of the plant using data reconciliation technology.** Data reconciliation techniques have been available for some time. Today, process simulators can be linked with real-time data. After matching the model to that data, a validated digital version of the process is established.

- **Use a pipe segment or a flash vessel to represent pipes, separators, or something more abstract, such as multiple unit operations.** Many unit operations in simulators have multiple calculation options built in that can accomplish the desired task without adding all the equipment in the field to the model itself.



It is easy for busy professionals to get caught up in the impressive new features, and new users may not be aware of all the legacy tools available in the program. So, to get the most value from a process simulator, consider whether all the available technology is being utilized to its full potential.

This excerpt is based on a larger article which highlights several more features available in **CHEMCAD** that users may not be taking advantage of. The view the article in its entirety visit:

www.chemstations.com/Value

Inspect, Analyze, and Solve Waste Heat Boiler Problems

HRST Inc.'s engineers, technicians, and designers have been using a three-step motto for almost 25 years: Inspect. Analyze. Solve. Taking this approach to every Waste Heat Boiler (WHB) project, HRST can achieve the best possible results and provide well thought-out solutions to problems.

INSPECT.

HRST's experience from 300+ annual inspections give them insight to common O&M issues, maintenance trends, and best practices. HRST offers several inspection services for Waste Heat Boilers:

- Pre-Turnaround
- Standard Turnaround Visual Inspection
- Advanced Turnaround Inspection Execution
- Enhanced Inspection Services

ANALYZE.

HRST's thermal analysis software can help any facility's team better understand boiler performance for process upgrades, monitoring service life, and failure analysis. HRST offers:

- Process and Performance Upgrades
- System & Component Design
- Quantify Thermal Effects

SOLVE.

HRST takes experience from inspections and problem analysis to develop innovative design solutions. These solutions often become products for clients, including:

- Retrofit Pressure Parts
- System Re-designs
- Burner Viewports
- Piping Penetration Seals
- Complete Liner Systems

HRST also provides technical field services to support projects. HRST expert guidance from Technical Field Services can offer:

- Turnkey Solutions
- Repairs
- Installation
- Vendor Surveillance
- Quality Assurance

Globally, HRST engineers, technicians, designers, field advisors, and project managers are committed to helping clients avoid and solve costly boiler problems. HRST also provides training on-site or off, with HRSG Academy (twice a year), on-site training, and on-demand remote training. Visit **www.hrstinc.com** for more information.

Alleviate headaches caused by faulty steam traps

TLV's TrapMan system uses a combination of ultrasonic and temperature measurements with empirical data to accurately diagnose a steam trap's condition

Properly working steam traps save time and money, and increase safety

Leaking and blowing steam traps with resulting energy loss and back pressure can hurt operating performance. Condensate backing up in a steam system from a blocked trap can potentially cause damage to critical equipment or reduce process performance. Opened bypass valves, to drain the steam system to grade, create a waste of energy and potential safety issues. All these headaches can be relieved through a sustainable steam trap management program based on **TLV's** TrapMan system for testing and reporting.

TrapMan is the first diagnostic instrument combining both ultrasonic and temperature readings with an empirical database to make an accurate automatic judgment of a steam trap's operating condition. If the steam trap is leaking, TrapMan can estimate the steam loss based on a correlation of the measured ultrasonic signature to laboratory data of losses for that specific steam trap model. The TrapMan system has over 4,200 unique signatures for different makes and models of steam traps. Automatic diagnosis results from the TrapMan system are accurate and repeatable regardless of the tester since the unit is making the decision and the hardware design helps eliminate variations due to human error. Judgement accuracy has been independently validated by Hartford Steam Boiler.

The TrapMan system includes powerful database software which provides the capability to retain historical test and installation records, allowing for detailed root cause analysis, reporting, and stewardship of a sustainable management program. The software can also be configured to a user's specific needs for inspection routes, capture of unique plant data, planning preventative maintenance and monitoring activities.

The TrapMan unit is easy to learn, weighs only 2 lbs and is intrinsically safe. Potential users can learn more about TrapMan's ability to enhance productivity, reliability, safety, and energy efficiency benefits at **www.tlv.com**

Plastic Control Valves Handle Corrosive Chemicals

Collins 2-in. valves and actuators are specially designed to handle corrosive fluids – acids, bleaches, chlorine, pH control – and aggressive environments

Collins Instrument Company's line of economical 2-in. flanged plastic control valves handle corrosive liquids including hydrochloric acid, caustic, sulfuric acid, and many others. With bodies of either PVDF or polypropylene, these highly-responsive control valves are specifically designed for use with corrosive media and/or corrosive atmospheres.

Suitable for applications in numerous industries, including chemical, petrochemical, pulp and paper, and municipal, these valves are extremely corrosion-resistant, and feature fast-acting positioning (stroke rate approximately ½ in./s). They are available with a wide selection of trim sizes, in globe, angle, and corner configurations.

The differential-area piston eliminates the necessity for auxiliary loading regulators. All actuator parts apart from the integral positioner are molded of glass-filled, UV-inhibited polypropylene. Before shipment, the aluminum positioner and a portion of the cylinder are immersed in Dip Seal to provide atmospheric protection.

Plastic valves and actuators from Collins

The integral positioner eliminates the need for external linkages which are subject to corrosion and malfunctioning. Valves may also be furnished without a positioner for on/off applications.

Collins also offers a plastic pneumatic actuator. The combination of a plastic actuator and a plastic valve body provides an effective way to handle both corrosive materials flowing through the valve, and harsh environments that can attack the outside of the valve and actuator. Collins plastic control valve packages withstand salty marine atmospheres as well as industrial environments that are too corrosive for metal valves and actuators.

Collins actuators incorporate a unique internal locking ring to attach the cylinder to the yoke. A semicircular groove is machined inside the lower edge of the cylinder, and a matching groove cut in the yoke. When the yoke and cylinder are assembled, a flexible polypropylene rod is inserted into the groove through a slot in the side of the cylinder, securing the two sections together.

Along with its corrosion resistance the Collins control valve features a stem packing arrangement that virtually eliminates the problem of fugitive emissions, thereby protecting the environment.

Located on the Texas Gulf Coast in the town of Angleton, Collins Instrument Company has been serving the chemical and petrochemical industry for over 65 years. **www.collinsinst.com**

Valve Manufacturing Done Right

Inline Industries, a California corporation, manufactures industrial valve products for the U.S. and international marketplace. Inline specializes in the production of high performance, corrosion resistant ball valves and automated systems. Inline delivers exceptional value to customers by providing the three most important elements they look for in a manufacturer: quality, availability, and price.

In today's climate of competitive pricing, contract manufacturing of components has become a way for many valve companies to enter the market or to remain in the game. Unfortunately, quality and delivery can often suffer as a result. Inline Industries manufactures products in its own facilities, sustaining internal quality control while maintaining extensive inventories. With Inline, clients are free to focus on plant operation, rather than worrying about equipment quality and delivery.

Inline's staff provides real-time factory support to address technical questions. Inline offers sole source automated systems with pneumatic or electric actuators, solenoids, limit switches, and positioners. Product can usually ship within a couple of days. Additionally, Inline is able to modify existing products or manufacture new designs to meet your specific O.E.M. requirements.

By providing a broad range of high-quality products at competitive prices, Inline offers customers a significant advantage in today's marketplace. **www.ballvalve.com**

Saint-Gobain NorPro Provides Full Line of Support Products and Security of Supply to Customers Worldwide

Reactor shows full line of Saint-Gobain NorPro support products from top to bottom including Pentarings, MacroTrap XPore 80, Catalyst Carriers, and Denstone support media.

Saint-Gobain NorPro has been a global leader in developing support media and catalyst carrier technologies for their customers in the refining, chemical processing, and related markets for more than 70 years. Saint-Gobain NorPro operates a number of regional manufacturing plants that are strategically located in the United States, Europe and Asia – allowing for global supply security for their customers.

Saint-Gobain NorPro launched their leading support media brand Denstone support media in the 1950s when their flagship Denstone 57 product was released. Today the Denstone support media brand includes a number of products engineered to support a variety of demanding applications. Denstone 2000 support media, Denstone 99 support media, and Denstone deltaP support media each offer unique attributes that help customers improve their reactor performance. Even in the most demanding of environments, Denstone support media delivers reliability.

In addition to Denstone support media, Saint-Gobain NorPro has developed innovative bed topping media solutions that help to reduce pressure drop in the reactor. Their Pentaring shaped media is a dense media that allows for sufficient hold down capabilities, while having a high void fraction and increased surface area to provide a reduction in pressure drop. Their MacroTrap XPore 80 guard bed media product works to trap particulates and soluble iron into its large pores before they reach the catalyst bed – helping extend the life of the catalyst bed.

Finally, Saint-Gobain NorPro is the largest supplier of merchant catalyst carriers in the world. Saint-Gobain NorPro works closely with customers to co-develop catalyst carrier solutions that deliver improved catalysts with improved **selectivity, activity and extended life.** One of Saint-Gobain NorPro's newest catalyst carrier innovations is their unique Accu sphere catalyst carrier technology. Accu spheres feature an average diameter anywhere between 0.3 mm and 4 mm with uniform size, and can be manufactured with flexible chemistries and pore structures. With this innovation, production operations can expect significantly increased output in fixed reactors, as well as in slurry or moving reactor processes.

For more information on Saint-Gobain NorPro products or to request a free consultation visit **www.norpro.saint-gobain.com.**

End-to-End Turnaround and Retrofit Planning Reduces Costs and Outages

What should you expect from a turnaround or retrofit project? A provider strategically positioned for fast customer response in any time zone, with the field experience and technical expertise to get the job done right. **Zeeco**'s turnaround services mean you have a single point of on-site contact for all your fired equipment during a planned shutdown. If you need to retrofit burners or reduce emissions, trust Zeeco for an end-to-end gas or hydrogen firing burner retrofit solution.

Our streamlined system ensures customers all planning and project execution is managed quickly and efficiently through a single point of contact, and our Gulf Coast facility ensures help is never far away for regional facilities. In fact, customers around the world have learned to rely on Zeeco's proven five-step turnaround management process.

SURVEY: Conduct inspection of equipment on-site and meet facility turnaround scope guidelines 12-18 months ahead of the planned turnaround
REPORT: Submit inspection report to the facility, typically within a few weeks after the combustion survey
PREPARE: Procure parts and service contract(s) 6-9 months ahead of the turnaround
EXECUTE: Perform site maintenance during the turnaround
COMPLETE: Provide necessary documentation after execution, typically within a few weeks after the turnaround

Zeeco can supply parts for all Original Equipment Manufacturers' (OEM) combustion equipment, with competitive pricing and rapid delivery. Our engineers are industry experts with a customer-first mentality. With Zeeco combustion specialists on-site, rest assured that your equipment will be installed and commissioned properly – avoiding costly mistakes that affect future performance.

Whether you face a full-scale emergency or a simple maintenance need, renting the right combustion equipment can be frustrating. ZEECO combustion rentals span the scope and capacity to keep any facility's essential operations online during both planned and emergency flare outages. Our rental flare systems are supported entirely by ZEECO turnkey combustion services and can keep specific processes online or eliminate the need to fully de-inventory plants - shortening turnarounds by days. ZEECO rental equipment includes flare systems, flare monitoring and control systems, thermal oxidizers, and vapor combustors. Our aftermarket team delivers the same attention to detail, engineered expertise, and on time, on spec performance – whether you have ZEECO equipment or not. From turnarounds through retrofits and rental equipment, Zeeco's project management and engineering expertise consistently deliver the outcomes our customers demand. For more information, contact sales@zeeco.com or call 918 258 8551. **www.zeeco.com**

IIoT

special advertising section

CHEMICAL ENGINEERING

Access Intelligence

Inside:

Improved customer service with BEUMER Smart Glasses:

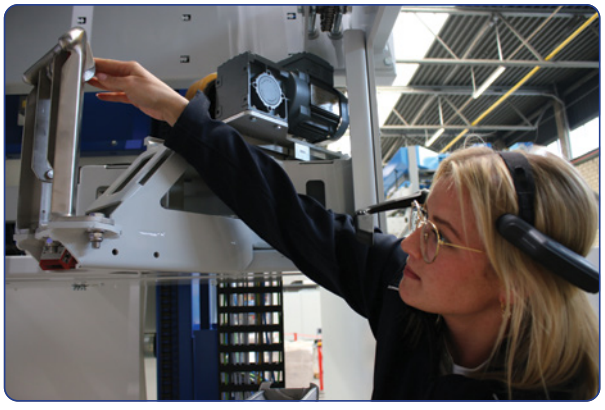
The virtual view

If faults and downtimes occur in machines and companies are unable to rectify them as quickly as possible, this can be expensive for them. With the BEUMER Smart Glasses, the BEUMER Group has developed a pioneering product that helps users to avoid precisely this quickly and easily: BEUMER Customer Support employees look over the shoulder of the customer's service technician virtually and solve the problem together with him. Remote commissioning is also possible.

The employee at the machine puts on the glasses and starts the BEUMER Support App via voice command. He transmits a service number and a pin code to the hotline, and the connection with image and sound is established securely. The BEUMER technician receives the same image that the customer sees. This means that he can give him instructions directly and display all relevant information in the field of vision. The employee has both hands free to follow the expert's instructions and perform the necessary actions. In this way, faults can be solved quickly and precisely – at any time. BEUMER experts are available around the clock, seven days a week. Language barriers or a lack of specialist knowledge are therefore no longer relevant when troubleshooting. Based on the recorded images, the experts can better clarify with the operator why the fault occurred in the first place.

Looking into the distance with smart glasses

With the digital solution, customers can not only be helped in case of malfunctions or downtimes of existing plants. Remote maintenance is also possible, in which BEUMER experts connect to the system – regardless of the time or day. This increases the availability of the machines, as no long journeys are required. In addition, there is the option of remote commissioning: The Corona pandemic is massively changing the travel behaviour. Due to travel restrictions, the technicians cannot always be on site. Nevertheless, it is important to get new machines up and running quickly. The data goggles allow an overview of the entire system: BEUMER Customer Support sees the same as the wearer on site and can directly prescribe the correct actions. In this way, he guides the user step by step through commissioning. The BEUMER experts can react flexibly with this procedure.



BEUMER Customer Support sees the same as the carrier on site and can directly specify the correct actions.

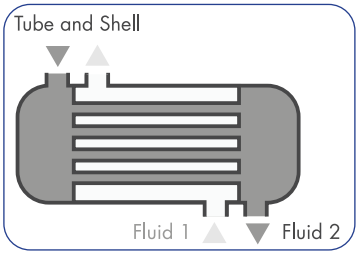
www.beumer.com

Predict Heat Exchanger Fouling

Reduce the downtime of heat exchangers by building predictive maintenance programs and digital twins with MATLAB

Cleaning heat exchangers is expensive. Maintenance can cost hundreds of thousands of dollars annually. However, operating a fouled exchanger affects the energy efficiency of the process by requiring additional utilities such as steam and natural gas. Hence, it is important to clean neither too often (too costly and higher HSSE risk) nor too infrequently (higher operational cost and low efficiency). Implementing a predictive maintenance program can address these issues. By estimating the remaining useful life (RUL) of exchangers, process engineers can take timely action to both prevent unexpected equipment downtime and reduce unnecessary maintenance expenditures.

Key to developing a predictive maintenance program is having a finely tuned first-principles model for the heat exchanger along with appropriate sensor data. **MATLAB** allows engineers to build models of heat exchangers using prebuilt libraries of equipment. Simulink and Simscape allow engineers to perform rigorous heat and mass transfer calculations and incorporate pressure and temperature-dependent behavior of fluids. They can also assess the effect of temperature on component and process-level performance. By tuning the model to match sensor data using Simulink Design Optimization, engineers can create a physics-driven, up-to-date representation of the heat exchanger in the field. This digital twin is then operationalized to make accurate predictions of heat exchanger performance.



Once the digital twin is created, Predictive Maintenance Toolbox lets users estimate the RUL of exchangers. The toolbox provides multiple functions and an interactive app for extracting and ranking features for exploratory and predictive analytics. Failure criteria for components, including time, pressure, or temperature-based conditions, can be specified, allowing engineers to track system changes and determine the presence of anomalies and faults. This approach enables the detection of any drift in the operation of the heat exchanger so that operational issues, such as fouling, and off-spec products can be mitigated.

Engineers and operators need to use the validated digital twin in an operational environment. Standalone executable applications and dashboards can be created with App Designer and MATLAB Compiler. This way, models built in MATLAB can be either deployed onto the DCS or shared with anyone via an internal web application without involvement by IT.

www.mathworks.com/solutions/chemicals-and-petrochemicals

Asset Integrity Management Software with 3D Digital Twin

The **Antea** Platform is a flexible, risk-based inspection driven asset integrity management software with 3D digital twin integration, fully equipped with the latest in IIoT technologies to digitally transform your plants and usher you into Industry 4.0. Antea was originally founded by chemical engineers, and thus its innovative software solutions understand the needs of chemical operators – whether single site, multi-site enterprise, or anywhere in-between.

Digitally Transform Your Plant

Antea's asset integrity management software is configurable with any multitude of plug and play modules – including risk based inspection, inspection data management software, mobility, integrity operating windows, and many more – making it scalable to a plant's individual and unique needs.

Eliminate information silos and visualize the live condition of assets in real-time with innovative digital twin technology. It bidirectionally links point cloud data, P&IDs, CAD, remote sensor and IIoT data for 3D visualization of all assets with the click of a button. The comprehensive suite of mobile solutions make it possible to access and input data via mobile device, and compatibility with wearable devices make it possible to conduct remote collaboration and remote assistance between team members with hands-free reporting.

Data Management as a Service

Of paramount importance to any asset integrity management program is the quality and consistency of its database. Antea backs up its innovative software solutions by offering ongoing, onsite or remote data management services to ensure the database is optimized and evergreen.

API 580/581 Validated

Antea RBI has been validated to API 580/581 and is trusted by major companies around the globe – enhancing regulatory compliance while dramatically reducing inspection costs. Complete integration with all CMMS, ERP and SAP programs translate to reduced points of entry for data, no information silos, and a single version of the truth across all sites.

Globally Trusted

For over 32 years Antea has facilitated digital transformation for chemical, oil and gas, and power plants around the world – and they have never lost a customer. Sales inquiries: info@antea.tech

For more information about Antea's suite of software and data management solutions, visit: **www.antea.tech**

Subscribe to the AIM for Reliability podcast:
https://antea.tech/resources/podcast

IIoT - Unlocking the full potential of field instrumentation.

An ecosystem of connected devices can deliver significant efficiency improvements to any production process. From precise data to actionable insights, the IIoT can unlock the full potential of the field instrumentation of any chemical plant.

Endress+Hauser has developed Netilion, a digital service equipped with the tools to help chemical factories to start digitalizing their plants in a safe and simple way.

About 90% of **Endress+Hauser** field devices are equipped with digital capabilities. And yet, many of their users are not taking full advantage of the data produced by their instrumentation. Exploring the connectivity of devices could open up unparalleled new possibilities to drive the performance and safety of chemical operations. Creating an Endress+Hauser digital ecosystem would allow easy access to crucial equipment data, such as obsolescence status, instrument documentation, or make a self-diagnostic. The information obtained from these data may be the lever to data-driven, informed decisions, potentially increasing reliability, reducing risk, and lowering the costs for stock and operations. Ultimately, this will result in increased control over processes, as the pool of information available is compiled, analyzed, and monitored. Quick responses in emergencies and critical operational activities can be based on precise data and perfectly managed digital documents.

Major trends reshaping the operating models of chemical companies include technological advances, shifting customer requirements, and increasing pressure on cost and productivity. A digitalized chemical factory opens the door to multiple optimization opportunities, even in industries with a tradition of continuous improvement. Nearly every stage of the manufacturing supply chain offers a starting point for optimization. The wide range of new possibilities can be illustrated across the horizontal and vertical business processes, from eProcurement and smart commissioning to digital-supported maintenance and "plant health apps."

Endress+Hauser has been a trustworthy partner in implementing digital services. Netilion has a straightforward implementation, with a standard offering various digital services. The Netilion Connect API module can be utilized for either data integration projects or the development of individual applications. There are also different options to explore field connectivity, unlocking the digital potential of devices you may already have. The development process of the products was certified group-wide according to IEC 62443-4-1. Netilion also fulfills the requirements of ISO 27017. With the support of a partner like Endress+Hauser, whose expertise covers not only hardware automation level, but also IIoT, you would take a significant step towards the future of manufacturing.

More details on Netilion? **www.netilion.endress.com**

Electric actuators for Industrial Ethernet

AUMA actuators support Profinet, EtherNet/IP and Modbus TCP

AUMA electric actuators support the Industrial Ethernet standards Profinet, EtherNet/IP and Modbus TCP, making the multiple benefits of Industrial Ethernet utilisable at field level.

Profinet, EtherNet/IP, Modbus TCP – Industrial Ethernet protocols are increasingly gaining ground for field device integration in the chemical process industries. Offering outstanding connectivity, combined with simple and robust transmission technologies, these protocols are key enablers for enhanced data integration, intelligent analytics and IIoT applications.

AUMA electric actuators support these standards and can be easily integrated in Profinet, EtherNet/IP and Modbus TCP environments, enabling plant managers to fully benefit from the enormous potential to optimize processes and maximize plant availability.

With bandwidths up to 100 Mbit/s, AUMA actuators provide reliable and rapid exchange of both cyclic process data and acyclic diagnostic data from the actuators. The wide range of diagnostic data that is automatically logged by the actuators is immediately available at network level and can be further used for analysis, process visualisation, or simulation, facilitating condition-based predictive maintenance and efficient asset management.

Providing utmost flexibility, the actuators can be integrated into line, star and loop topologies, using different transmission media such as copper cables, optical fibres and wireless technologies. AUMA provides standardised device descriptions as GSDML or EDS files and Field Device Integration Packages, thus facilitating device integration.

www.auma.com

Economic Indicators

2020 2021 2022

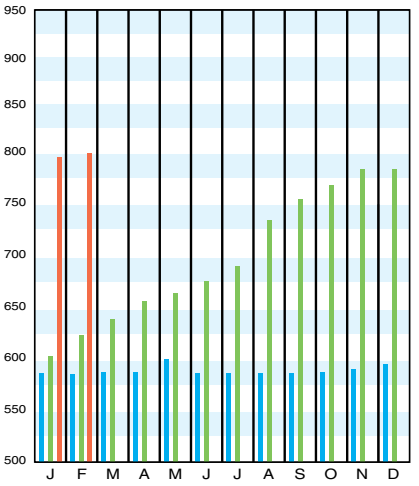
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Feb. '22 Prelim.	Jan. '22 Final	Feb. '21 Final
CE Index	806.3	797.6	637.8
Equipment	1,022.9	1,009.2	782.8
Heat exchangers & tanks	874.7	860.3	675.3
Process machinery	1,018.7	993.1	771.1
Pipe, valves & fittings	1,469.7	1,457.0	1,052.6
Process instruments	557.4	568.9	450.7
Pumps & compressors	1,225.5	1213.2	1,111.5
Electrical equipment	725.7	698.9	575.4
Structural supports & misc.	1,126.5	1,115.5	847.0
Construction labor	345.4	345.6	333.6
Buildings	825.7	831.3	653.4
Engineering & supervision	310.3	310.7	310.8

Annual Index:
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2

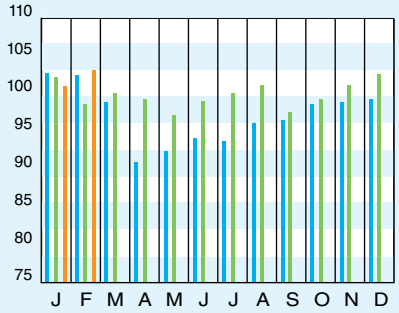
Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)



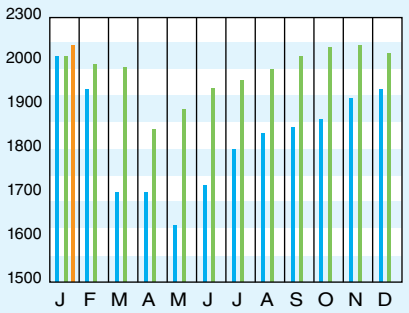
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS		YEAR AGO	
CPI output index (2017 = 100)	Feb. '22 = 100.4		Jan. '22 = 98.8		Dec. '21 = 99.3	Feb. '21 = 90.9
CPI value of output, $ billions	Jan. '22 = 2,134.7		Dec. '21 = 2,108.0		Nov. '21 = 2,103.8	Jan. '21 = 1,816.1
CPI operating rate, %	Feb. '22 = 79.9		Jan. '22 = 78.7		Dec. '21 = 79.1	Feb. '21 = 72.4
Producer prices, industrial chemicals (1982 = 100)	Feb. '22 = 339.4		Jan. '22 = 334.7		Dec. '21 = 335.8	Feb. '21 = 268.9
Industrial Production in Manufacturing (2017 =100)*	Feb. '22 = 101.5		Jan. '22 = 100.4		Dec. '21 = 100.3	Feb. '21 = 94.6
Hourly earnings index, chemical & allied products (1992 = 100)	Feb. '22 = 195.5		Jan. '22 = 194.5		Dec. '21 = 194.4	Feb. '21 = 194.8
Productivity index, chemicals & allied products (1992 = 100)	Feb. '22 = 94.4		Jan. '22 = 95.0		Dec. '21 = 93.7	Feb. '21 = 82.9

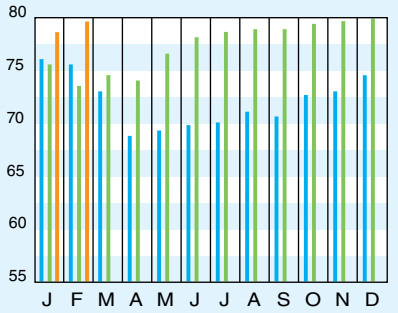
CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the February 2022 *CE* Plant Cost Index (the most recent available) was higher than the previous month, continuing the steep monthly increases observed throughout 2021. The upward trend has been driven largely by equipment costs — the Equipment subindex rose in February while the Construction Labor, Buildings and Engineering & Supervision subindices all fell slightly. The current CEPCI value now sits at 26.4% higher than the corresponding value from February 2021. A larger-than-usual variance between the preliminary and final January 2022 values, coupled with a calculation error, resulted in upwardly revised values for the final January 2022 CEPCI, compared to the preliminary numbers for January.